

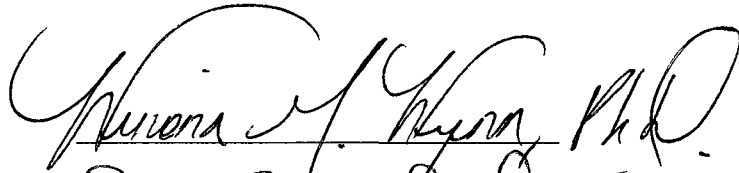
SCIENCE EDUCATION IN RURAL AMERICA:


ADAPTATIONS FOR THE IVORY TOWER

By

Gregory S. Van Doren

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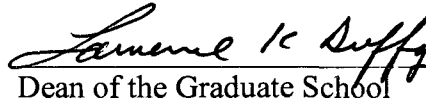


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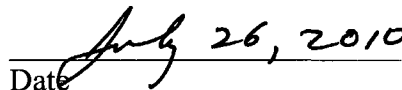


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SCIENCE EDUCATION IN RURAL AMERICA:  
ADAPTATIONS FOR THE IVORY TOWER

A  
THESIS

Presented to the Faculty  
of the University of Alaska Fairbanks

in Partial Fulfillment of the Requirements  
for the Degree of

DOCTOR OF PHILOSOPHY

By

Gregory S. Van Doren

Fairbanks, Alaska

August 2010

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### Abstract

This thesis illustrated what can happen when academic culture disconnects from the cultures surrounding it. It showed that formal school environments are not always the best places to learn. A discussion of the debate between coherence and fragmentation learning theories illustrated academic chasms and a mindset that science education must originate from within ivory towers to be valued. Rationales for place-based science education were developed. Two National Science Foundation initiatives were compared and contrasted for relevance to Native Science education (a) Informal Science Education and (b) Science Education for New Civic Engagement and Responsibilities. A National Science Foundation instrument, known as the Self-Assessment of Learning Gains, was selected to field-test measures of learning science outside of university science courses. Principles of chemistry were taught in community workshops, and those participant self-assessments were compared to self-assessments of students in introductory chemistry courses at two universities. University students consistently claimed the greatest learning gains, in the post-course survey, for the same areas that they claimed to have the greatest understanding, in the pre-course survey. The workshop participant responses differed, depending upon location of the learning environment. When held in a university laboratory, ideas were not related to other cultures, even when a Native Elder was present to describe those relationships. When held in a cultural center, those relationships were among the highest learning gains claimed. One of the instrument's greatest assets was the ability to measure *reactions*, level 4 of Bennett's (1976) hierarchy of evidence for program evaluation. A long-term commitment to informal science education (not short-

term exhibits or programs), combined with negotiated place-based education was recommended as a crucially needed initiative, if relationships between universities and Native American communities are to improve. Some chasms created within ivory towers may never be bridged. Yet, those ideological chasms do not have to exist everywhere. The realities of working in the natural world and the practice of addressing multitudes of community challenges can alter perspectives, when horizons change from the edge of one's desk to those that meet the sea or sky.

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## Preface

This thesis represents a traveler's search to find a place, somewhere between his professional colleagues in formal learning environments and the diverse cultures and people he has worked with. In that place, questions are asked about knowledge and how to teach or learn science in various learning environments. The objectives were twofold: (a) to expand an earlier call for *Domestication of the Ivory Tower* (Barnhardt, 1986) and (b) to determine if the National Science Foundation's SENCER-SALG, an assessment tool, would function in other learning environments as well as it had within university science courses.

For one who has taught within educational institutions and collaborated among diverse rural communities very far from those institutions, it has been difficult to reconcile good words, spoken and written within ivory towers, to external realities – the lived experiences of rural people. Faculty from the University of Alaska Fairbanks (UAF) took an interest in my efforts and an invitation was extended to transfer my graduate research program from the University of Washington to UAF, and to combine it with my community efforts with the Yakama Nation. Space between university and community was opened for me to study issues in science education related to alternative world views and the lives of rural Native Americans.

I am especially grateful to my SENCER Fellow colleague, Dr. Larry Duffy, for his invitation to study at UAF, for his ability to guide the research, and for his committee selection. Dr. Barnhardt's lifelong devotion to bridging gaps between education and rural communities provided the inspiration for me to continue, when I was ready to give up.

Dr. Gerlach demonstrated his ability to work both within and without institutional walls, providing me with a prospect of returning to similar work. Dr. Clausen asked the tough questions expected of all scientific colleagues, reminding me that skeptical inquiry has served scientists well in the past and continues to do so. Dr. Winona Wynn was an ever-present advocate for my efforts and provided guidance from a Native American perspective.

Students have adapted to academia for centuries; this research was directed towards adapting institutions to local communities. Rather than attempting to develop entirely new chemistry curricula, basic chemistry principles were taught, within different learning environments, ranging from formal university classrooms and high school workshops to informal interactions with elders at community cultural centers. The student self-assessment instrument was then analyzed for learner reactions and understanding. Through corroborative stories, literature citations, and the adaptation of an existing assessment instrument, this thesis aimed to (a) to narrow the separation between formal and informal learning environments, (b) to present a rationale against a one-size-fits-all educational system, and (c) to obtain an instrument that would describe learner reactions in multiple learning environments and provide evaluators with evidence for learning.

Without the collaboration of colleagues and mentors, this work would never have been written. In addition to the UAF thesis committee, I would like to thank NSF colleagues David Burns and Cathy Middlecamp, for their SENCER guidance, Steve Carroll for his assistance with the SENCER-SALG, and Myles Boylan, as my NSF-STEP project director. I also thank my science mentor Pat Kerr-Falco, for her life-long

dedication to making science understandable by anyone, all my Native American colleagues who have patiently guided my journey along unfamiliar paths, and my wife, Elena, for sacrificed time and treasure to this thesis.

## **Chapter 1**

### **“Are You as Smart as the Books or the Woods?”**

#### **1.1 Introduction**

This thesis is introduced with three personal stories, each illustrating how different learning environments affected both teacher and students. It was hard to distinguish who was teaching from who was learning. These experiences comprise a representative sample of events, which have been personally witnessed for over 40 years, within both formal and informal learning environments. Before discussions of learning theory and the term *concept*, prior to challenging the wisdom of conventional academic education as a one-size-fits-all program, the stories cut right to the heart of the matter, suggesting that formal school environments are not always the best places to learn.

#### **1.2 Book Smarts**

The following story is central to this thesis. It was a driving force to either attempt change in formal education, or a vow to set ivory towers on fire. It represents power and authority replacing compassion and common sense; moreover it illustrates what can happen when academic culture is secularized and disconnected from the cultures that it is embedded within or has not embraced.

From the beginning of my teaching experiences in formal education, I have encountered situations unlike any faced during my twenty-year career as an agricultural extension agent and advisor. Soon after obtaining an emergency substitute teacher certificate, I was assigned a room for a week, the in-house detention room at a middle school, in a poor, rural, minority community. The windowless, bare-walled room was



comparable, in size, to a two-bed prison cell. The solid door gave only a muffled indication that there was any world outside. Inside, was an old empty desk plus six tiny cubicles, each occupied by sallow, green-faced, 11-13 year-old students, peering up under artificial fluorescent lights. It was barely two weeks into a new school year. The room was stuffy, poorly ventilated. The hard plastic chairs were uncomfortable and lack of room for movement or exercise only made limbs ache more. It was a far cry from extension work, scouting nearby 640-acre square mile grids of wheat fields, stretching from one horizon to another.

The rules were simple enough. Nobody was allowed to talk, look around or do anything except read or work on assignments in manila folders, which were sent by various teachers, throughout the day. Students assigned to in-house detention were only allowed restroom breaks when all other students were in class, so they would not meet anyone in the halls. An intercom call to the office brought an assistant to the door, to escort each one to the restroom. The group was also escorted to the cafeteria, 15 minutes prior to the other students, to silently pick up their lunch, before returning to their cubicles to eat alone. The substitute teacher was not expected to do anything but enforce the rules. Seven hours in there seemed like forever.

Ironically, the evening after that first day, my pre-service teacher course professor lectured on the abuse and desecration of culture at Indian boarding schools of the 19th and 20th centuries. That day's observations indicated, for some students, things hadn't changed very much. In both cases, forced assimilation (*de facto* incarceration), within a compulsory education system, without institutional concern for people's life experiences,

seemed contrary to being ". . . endowed, by their Creator, with certain unalienable Rights . . ." (U.S. Declaration of Independence, 1776, para. 2).

The next day, rules were ignored and the students were engaged in conversation. One young man was lethargic and incapable of concentrating on assignments. When asked what time he went to bed, he indicated that it was sometime after 3:00 a.m. Allowed to speak freely, he indicated that his mother and her boyfriend often got drunk and physically fought each other, a lot. He said that the boyfriend also beat him and his younger brother. When the mother's boyfriend was around, he would take his brother out of the house, and they would roam the streets until the adults fell asleep, to avoid getting beat up. This was all reported to the front office. Child Protective Services took the two brothers into protective custody and that young man was never seen again. It was disheartening to see that professional teachers were punishing him for trying to protect his younger brother; that nobody had bothered to ask simple questions or to listen to his story. He confided in a total stranger; whether he was helped for doing so may never be known.

Another young man was able to complete any assignment brought to him, within minutes. He spent most of his time rapidly reading thick Stephen King novels, at a reading level far above most of his peers. When he spoke, it was obvious why he was sent to in-house detention. With all the clarity and nonchalant language of a sailor, every other word out of his mouth was profanity. It appeared that he lived in an environment where that language was commonplace, as he did not seem to be willingly trying to offend anyone. He said he preferred in-house detention because he could do his work

faster than in a regular classroom, without getting into more trouble. His goal was to get back to reading his books. School was too easy for him, at least the academic part. His language was unacceptable, yet his scholastic ability should have placed him in a gifted student program, instead of in-house detention. Without the profanity, he could have been in a college-preparation program.

A young woman was sent to in-house detention for shoving and hitting someone who said she was stupid. Her reading and writing capabilities were barely first-grade level, yet she had wonderful manners and could draw beautiful pictures. Conversation revealed that both her parents worked multiple jobs, that she and several younger siblings were latchkey children, who basically raised themselves. She appeared to have more parenting and social skills than the parents of either of the boys aforementioned, yet because she hit someone for saying she was stupid, she was being deprived of the very education she needed. For seven years, she sat in buildings full of certified teachers and books, yet remained unable to read.

### **1.3 Woods Smarts**

This story illustrates the never-ending saga of cultural conquest, which in the name of education, has repeatedly attempted to “civilize” cultures, but has destroyed them instead. It represents personal resolve to never force others to have to choose between their culture or Western education. The burning of villages has destroyed as much knowledge as has the burning of libraries.

It was a hot summer day in the wooded savannah of Moçambique in 1994. My bottled water had run out, and it would be several hours before we returned to Vilankulo.

From my perspective, there was no water anywhere. The Portuguese interpreter spoke in Xitswa to a couple of men. They dug into the ground and used their machetes to sever a tree root and taper the end of it. The interpreter told me to sit on the ground while one of the men held the end of the root to my mouth. Out poured water - lots of it - sweet and refreshing. With smiles and gratitude, these educated men were thanked, not for their book smarts, but for their woods smarts. Replenished, an interview was recorded, one that would alter personal perspectives forever.

As a contract evaluator (Van Doren, 1994), I had been sent to determine the effectiveness of a non-government organization's (NGO) agricultural extension program, which was funded by the United States Agency for International Development (USAID). At that time, Moçambique was labeled the poorest country in the world, with a per capita annual income of less than \$10. Most of that money was retained in the large capital city of Maputo. Illiteracy surpassed 90% in most of the rural areas. The NGO's lead extension director had quit just months before the end of the 3-year USAID project, taking all his notes with him. The program had to be evaluated by visiting with the participants. In six weeks, over 160 farmers were interviewed, plus the employees of the NGO, along with professionals from several other organizations, who had worked alongside them.

During one interview, another NGO's director opined on the effectiveness of the food-for-work program and on efforts of extension workers to re-establish agricultural production, after nearly thirty years of warfare (few people living remembered how things used to be). One of director's greatest criticisms, of the NGO being evaluated, was the requirement that extension workers must have at least an 8<sup>th</sup> grade education before

entering agricultural training. “That’s a totally crazy idea,” he remarked. “People with an 8<sup>th</sup> grade education don’t want to do agriculture, they want to sit in an office!”

(Moçambique’s President had an 8<sup>th</sup> grade education). The director was insistent (a) that corruption and power, easily attained by anyone with minimal education, was destroying the cultural fabric of the rural people and (b) that they needed practical education, not a bunch of books. “People say that Moçambicans are poor, but they are rich.” “What do they need?” “They have all the land and the resources.” “You need \$2000 (a month) to survive in America.” “Here, you don’t need peanuts to survive, if it rains.” “It’s crazy to take these people out of the rural setting.” “You’re messing them up!” I looked around at all the smiling faces; people who had no idea what we were talking about. Those words, in the woods that day, echo in my mind as if they were uttered yesterday.

#### **1.4 Book Smarts in the Woods**

It was a beautiful October day in 2009. “Indian Summer,” some have called it. “Don’t bother the professional climbers!” With those words, we opened the bus door and the high school students scrambled out to experience some geological wonders known as The Feathers and Frenchman Coulee. Huge columns of basalt, towering 40-80 feet high, were formed from cooling lava, millions of years ago. Exposed and eroded by the catastrophic Columbia Floods, most recently about 10,000 years ago, the columns stood as sentinels above the deep coulee below. Two university students, from the west side of the state, had brought all their climbing gear and were just beginning their vertical ascent of one column.

Most of the students had walked across the road, to perch precariously along an unfenced 500-foot high cliff and gaze into the coulee. One student bounded up the trail instead, past the climbers at the base of the columns, up a pile of talus, then a broken cliff face, until within just minutes, he stood at the top of the escarpment. He stood above the “professional” climbers, who had barely made 10 feet of vertical ascent. He looked down at them briefly and gazed off into the coulee from his high vantage point, then bounded back across the escarpment and down the other side. A moment later, he peered between the bases of two columns and grinned. The “professionals” were not yet half way up to where this young man had already been to and returned. My jaw stood open in amazement. Noticing me, his teacher simply said, “We’re Indians.” “This is the land the Creator gave to us.”

Soon, another student brought a small rock to me. “This one is different,” he said. It was a shard of black obsidian, from hundreds of miles away. It was probably from a tool his ancestors had used when they camped here, long ago. He smiled and put the treasure into his pocket, satisfied with the possibility. Other students noticed white cliffs above the other side of the coulee. The diatomaceous earth they were pointing to was once at the bottom of a freshwater lake. A prehistoric forest once covered the area. Later, we visited the Ginkgo Petrified Forest. Other students wanted to know about the lichens and moss they found on the rocks, how far it was to the bottom of the cliff, why the floods came, where the water and the rest of the rocks went. Their questions were endless, their observation skills acute. Geology, history, archeology, climatology, biology, environmental science and physics were all part of the experience. This was a

laboratory and school that some professors only dreamed of, yet we were only there for half an hour, as there were other stops to make on this day-long geology tour.

These youth were descendents of people who would not have survived the catastrophic ice age floods unless they were at higher altitudes, in the mountains: hunting, lake fishing, digging roots or picking berries. Below them, 60 mph floodwaters, several hundred feet high, stripped away entire landscapes and civilizations, homes and relatives. When the waters finally receded, their former homelands would have been unrecognizable, either carried away or buried beneath hundreds of feet of sediment. They had to wait for the rivers to clear before the salmon returned, for years before the trees grew back. The mammoths and many other large animals were gone. They were few in number and they had to survive. Long before newcomers arrived, they studied their new world and learned from it.

### **1.5 Personal Paths**

My family and culture have always placed a high value upon formal education. Moving among schools, colleges and universities, it was necessary to learn many unspoken rules and methods of discourse, new academic languages and customs. Education departments had different rules and customs from science departments. Public universities differed greatly from private universities—in politics, beliefs and philosophies—a big shock to one who had been in parochial schools and universities since fourth grade.

In professional work, I learned that extension professors were not equal to academic professors (at least from the academic professors' viewpoint). Extension

faculty, who had the daily pulse of the community, were railed against for not following their administrators' directives, administrators who only got out during the annual "dog and pony show" tours of the state. Despite warnings, from dedicated field faculty and their constituents, initiatives were implemented, based upon the advice of academic professors, who spent their entire careers within ivory towers. They knew little about field operations. Within a twenty-year time span, extension faculty were reduced to 50% of their former number. With decreased public support and a re-directed extension program, the research and experiment stations soon began eliminating academic faculty, and some experiment stations closed. At the time of this thesis, all the agriculture-related degrees combined comprise less than 3% of my alma mater's graduates. This land-grant university abandoned both the people and the land, which supported it.

Retention of academic lessons, honed observational skills, and my acquired methods of teaching in diverse ways, some with books and some without, provided a basis for relating to other people, as the preceding stories exemplified. Foreign languages were learned in other homes, not in classrooms. Although classroom experiences comprised much of my formal education, farmers were advised, after listening to them and observing how they farmed. Advice was based not only on formal knowledge, but also from work experience on diverse farms, all around the world. Filipinos, Moçambicans, Ghanaians and Yakamas provided training unavailable in any books.

Nobody ever learned how to swim by only reading books or by doing static drills; they had to get into the water. In all my travels, it was observed that informal learning



environments far outnumbered classrooms, and there was much more to teaching and learning than lectures, books and labs.

Much of my personal knowledge is attributed to formal education, but I am concerned over its predominance in America today. Education impacts the lives and customs of peoples, often disregarding their values and beliefs. The virtues of formal education do not need to be extolled to academic peers. Rather, by pointing out pitfalls in formal education and arguing the need for informal education, it is hoped that some balance can be achieved, in education and in life. Changes could be made before some universities close, following the demise of their extension programs and research stations, which have already preceded them.

### **1.6 Summary**

The previous scenarios were chosen as an introduction to this dissertation because they really occurred and because they reflect paths I walked, as both a student and as an educator, within formal and informal learning environments. The scenarios reveal an educational philosophy and bias towards action: (a) value the unalienable rights of people and oppose actions which threaten them, including compulsory education, as it exists today; and (b) speak out against administrations perceived to be out of touch with the communities they were charged to serve. Yet, formal education is recognized for providing opportunities, and shelter, which fostered learning. Without that shelter, different paths might have been followed.

Formal learning opportunities can help those seeking knowledge. When among one's own culture, it can be harder to know the beliefs and values of others, if community

and family pressures discourage learning from outsiders. Books and lectures can provide knowledge, but if those who teach from books wall themselves off from communities, if they restrict what knowledge is taught, if they compel others to come to them for instruction, if they forget the outside world and stop learning from it, then they deny the existence of unalienable rights and their knowledge becomes irrelevant.

One of the reasons for personal interest in working more closely with indigenous peoples and third-world societies is that they are experienced in the natural world, one less cluttered by modern societies' technical substitutions. It is of no interest to proselytize or indoctrinate people into Western scientific thought, but if science is offered as a tool to address local issues – issues determined within a society, not imposed upon them from without, as a natural scientist, it has been observed that indigenous societies grasp relevant scientific ideas, select those they need and relate them to their world. Some people may not have academic credentials or speak the language of university discourse, but they have natural science abilities and knowledge, surpassing that of academic professors. This has been termed “woods smarts,” as opposed to “book smarts.”

Chapter 2 focuses on some issues in academic discourse, science teaching, power politics and estrangement from the natural world, issues primarily for those with book smarts. It describes coherence and fragmentation learning theories, in the language of ivory towers. Chapter 3 addresses some of the issues raised in Chapter 2, from the perspective of woods smarts, in the people's languages. The holistic views of Native Americans, presented in Chapter 3, contrast with the reductionist/analytical views in Chapter 2. Native voices call to academic professors to experience the natural world, to

venture outside the ivory towers. Chapter 4 reviews the history of the National Science Foundation's Science Education for New Civic Engagement and Responsibility (NSF-SENCEER) initiative, including the Self-Assessment of Learning Gains (SALG) instrument, both developed for use within university science courses. Chapter 5 reviews the results of an exploratory study, which used the SALG within informal learning environments, to compare those responses with responses obtained from university courses. Chapter 6 presents possible future directions, for community, place-based science education.

## Chapter 2

### “Ebony Within the Ivory Towers”

#### 2.1 Introduction

Two academic issues have reduced a university’s ability to communicate beyond the ivory towers: (a) the predominance of convoluted ideas with sophisticated language, and loosely defined, or undefined terms, and (b) tendencies to focus minds inwards, towards an individual world, rather than outwards, towards a dynamic world. This chapter reviews and integrates literature related to those statements. The following sections discuss issues in science education, definitions of science, the purposes of university science laboratories, debates about conceptual change, the term *concept* and opposing views in learning theory.

As ebony, a dark, heavy wood, contrasts with white ivory, formed from the dentin of teeth, my arguments in this chapter suggest that intellectual monuments can imprison minds; that competing schools of thought have created their own chasms, which separate them from each other. Academic intolerance may be just sophisticated pugilism. To wit, in the former suggestions, ebony can either make ivory ideas sharper, or cause them to sound flat. In the latter, the density of ebony is an advantage if a fight breaks out.

#### 2.2 Informal Science Education?

There has been considerable disagreement among educators and scientists, not only about the advantages or disadvantages of formal science education or informal science education (ISE) programs, but also about what comprises ISE, because ISE is often too narrowly defined. For instance, the National Science Foundation (NSF) has

defined and funded ISE activities, which are quite limited in scope. NSF-ISE grants have primarily focused on traveling science exhibits, planetarium programs, and science programs at zoos or museums. They are primarily short-term science education interactions, mostly in or near major cities. NSF-ISE is generally concerned with providing supplemental materials for formal schooling or after-school activity programs, all of which are planned and approved from within academia by formal educators.

The publication, *Learning Science in Informal Environments: People, Places and Pursuits*, (Bell, Lewenstein, Shouse, & Feder, 2009) was written entirely by a committee of academics, without the collaboration of anyone who works in an informal setting, such as the Cooperative Extension System, much less any elders from a rural indigenous community, who have been transmitting traditional ecological knowledge for millennia. The committee's penultimate question was, "Do people learn science in nonschool settings?" As the first sentence in their executive summary, that question provided evidence of bias. With their "discovery" of informal learning, now enlightened academics have wanted to ride in like cavalry, to show teachers and community leaders alike how to teach science outside of school. Regrettable failures, comparable to those of Custer and Napoleon, could result from such self-serving campaigns, when the knowledge of others is ignored.

Alan Friedman's (1995) paper, *Creating an Academic Home for Informal Science Education*, exemplifies a centralized, university-directed approach to informal science education, limited in scope and understanding because fellow academic professors were the only people consulted. Countless examples of program failures could have been

found if one examined the history of agricultural education and the Cooperative Extension System, which has existed for more than 100 years. Those failures could serve as warnings to university academic professors, who would venture beyond tower walls, that a different world awaits outside; that failure to integrate book smarts with woods smarts is courting disaster. Examples in foreign countries: crop disasters when sterile seeds were saved from hybrid plants; pesticide bottles which were used for mixing infant formula; tractors rusted away, with oil in the radiator and water in the engine, while people shared hand hoes and walked among thorns without shoes; starving people hauling water 4 miles, on their heads, to irrigate nitrogen-deficient tomatoes, while unrepaired wells sat 50 feet away (Van Doren, 1994; Van Doren and Azu, 1995). At home, Jim Hightower (1972), another former extension agent, wrote a damning article about the Cooperative Extension System, *Hard Tomatoes, Hard Times: Failure of the Land Grant College Complex*, in which he claimed:

Rural people, including the vast majority of farmers, farm workers, small town businessmen and residents, and the rural poor, either are ignored or directly abused by the land grant effort. Each year about a million of these people pour out of rural America into the cities. They are the waste products of an agricultural revolution designed within the land grant complex. Today's urban crisis is a consequence of failure in rural America. The land grant complex cannot shoulder all the blame for that failure, but no single institution—private or public—has played a more crucial role. (p. 10)

Ten to 20 years after Hightower's report, personal observations supported his

description of what was happening in rural America and within the Cooperative Extension System. Academic professors have ignored extension professors for decades; administrators have coerced extension agents to become more like academic instructors; and the Cooperative Extension System has become a mere shadow of its former existence. Depending upon one's point of view, that decline is either laudable or lamentable. Nevertheless, Informal Science Education (ISE), as defined and directed by academic professors, exemplifies a presumptuous position, already shown to be flawed, that academic professors know what rural communities want and need. Rural America has suffered enough.

On the other end of the spectrum, another NSF program, the Science Education for New Civic Engagement and Responsibility (SENCER) initiative, instead of looking for new worlds to conquer, is reforming science education from within, by allowing community partners to assist in educating university science students. While not all community-university learning relationships must revolve about big controversial issues in science, the SENCER approach has certainly improved relationships by choosing to do so. SENCER claims to have its origins in the Cooperative Extension system. They have the “cooperative” part figured out to some extent; they just need to decide how much of the university to haul along into the community. Chapter 4 discusses the SENCER program in greater detail.

### **2.3 Science and Transformative Education**

Understanding university science requires more than a cursory acknowledgement of institutional traditions, experiences and research methods of scientists—in essence

their culture. Educational reformers, who advocate for changes in science curricula, laboratory components or teaching methods, might do well to recognize their own cultural views and acknowledge those of students and local communities, regarding them with the same respect as they do academic cultures. This has not always been so.

One of the more radical views, held by some proponents of transformative education, is that all cultures are equal, except dominant cultures, which need to be deconstructed for the oppressed cultures to rise and build their own constructs:

To embrace the transformative approach, teachers must be willing to deconstruct their own existing knowledge, explore alternative perspectives critically, research and include voices and ideas other than those traditionally presented to us, and address their own roles in perpetuating racism and oppression (Cumming-McCann, 2003, p. 9).

One way of deconstructing science (as a discipline) is to assert that everyone is a scientist or “does science.” The resultant views about science, what it is, how it is done, vary as widely as people’s imaginations. If that reasoning were applied to its proponents themselves, everyone should also be an educator. School dropouts would be just as qualified as professors of education to train teachers; the illiterate could teach writing. The works of Dr. James A. Banks, Professor of Diversity Studies and Director of the Center for Multicultural Education, within the University of Washington’s College of Education, challenge the concept of a discipline-based education system and who decides what outcomes should be measured (Banks, 1996).

The etymology of the term *science* describes both a body or branch of knowledge



and a process of separating or dividing things from one another (Science, 2009). In 1957, when science seemed to be more uniformly accepted and understood than it is today, National Science Foundation Director Alan T. Waterman (NSF, 1958) presented a definition of science, as both a body of knowledge and a process:

What is science? The body of science represents the accumulated knowledge concerning the world we live in and how it operates. Increases in this body of knowledge are made by research, which is the active search to increase our understanding of nature. It is continually tested by observation and by experiment, and continually enlarged in detail, and in overall design. As science grows in scope and complexity, years of study and practice are required to perform modern research (NSF, 1958, p. IX).

It is this practice in observation and experimentation that is modeled in state university science courses, with increasing scope and complexity as the student progresses through years of study. That progression is an integral part of the search to increase understanding.

## **2.4 The University Science Laboratory**

Since millions of Americans have migrated from rural areas to large cities, many have only occasional interactions with the natural world. In the absence of that experiential interaction, the university science laboratory is where many students begin to make connections between their book smarts and the natural world. The importance of the laboratory in helping students understand the natural world has been reported since at least 1811 (Lunetta, Hofstein & Clough, as cited in Abell and Lederman, 2007, p. 394).

What has changed in the past 50 years, beginning with science education reform movements of the 1960s, is the volume of research and knowledge discovery courses, along with evolving policy recommendations regarding “the teaching, curriculum, and laboratory learning environments that promote desired science education goals” (p.433). Over the same 50 years, the greatest changes to laboratory learning environments, teaching and curriculum have occurred in the K-12 education system, which has struggled to provide evidence that all these changes have produced graduates more prepared for careers in science. Scientists cannot be convinced to overhaul university science courses if educational researchers cannot provide evidence of improved outcomes. Self-defined boards and committees of experts, in lieu of evidence, have proposed mandates.

The National Science Teachers Association (NSTA, 2007) has provided written evidence, in their position statement, of an attempt to establish uniform instructional policies in a K-16 system (which includes undergraduate university science courses):

For science to be taught properly and effectively, labs must be an integral part of the science curriculum. The National Science Teachers Association (NSTA) recommends that all preK–16 teachers of science provide instruction with a priority on making observations and gathering evidence, much of which students experience in the lab or the field, to help students develop a deep understanding of the science content, as well as an understanding of the nature of science, the attitudes of science, and the skills of scientific reasoning. (para. 2)

Who decided how science is to be taught “properly and effectively” or that making

observations and gathering evidence were the priority, for a “deep understanding of the science content?” An additional NSTA (2007) declaration stated:

NSTA strongly believes that developmentally appropriate laboratory investigations are essential for students of all ages and ability levels. They should not be a rote exercise in which students are merely following directions, as though they were reading a cookbook, nor should they be a superfluous afterthought that is only tangentially related to the instructional sequence of content. Properly designed laboratory investigations should:

- have a definite purpose that is communicated clearly to students;
- focus on the processes of science as a way to convey content;
- incorporate ongoing student reflection and discussion; and
- enable students to develop safe and conscientious lab habits and procedures. (para. 3)

That statement also raises some questions. Who decided what is developmentally appropriate or if development always occurs in the same sequence—in a culture, in a gender, in an individual? Who defines ability levels? Doesn't rote exercise have a place, especially in mathematical operations? Isn't following directions a test of ability? Who determines the content? Superfluous afterthought to one may be essential genius to one who sees another sequence. What made the NSTA recipe for success any better than another? If it looks like a cookbook and reads like a cookbook, it must be another cookbook.

Mandated university policies, to change what scientists do, or how they do it, are

a bad idea, especially when scientists disagree about those policies. Basic research is a large part of university research activity and funding. Historically, undergraduate courses for science majors have either prepared students for technical positions in science and industry, or for graduate school, where they continue to practice science as research assistants and become research colleagues in academic institutions, or work in national and private laboratories. Director Waterman of NSF (1958) also commented on a national policy for basic research:

It is that no agency, government or otherwise, can rationally attempt to formulate what individual scientists should do, and still less how they should do it. No scientific society would think of doing such a thing for its members. The scientists themselves know best what can be done and how to go about it. (p. X)

While academic freedom is not a free license to say or do anything, it is the freedom to practice the profession one has researched, studied and trained for, among colleagues and peers. In that arena, ideas are tested, critiqued, evaluated and accepted or rejected by a minority, majority, or all members of the peer group. To some, the peer review process may seem tyrannical, discouraging creative thought. Yet, individual scientists are still willing to defend their ideas, sometimes for decades, against the predominant views of their peers. I believe that most scientists would prefer arguments amongst themselves than being subjected to policies which would restrict their academic freedom, restrict the growth of science, or at worst, impose the views of non-scientists over them.

Research scientists, particularly in the *natural sciences*, may or may not teach university courses; if they do, they may only teach upper division or graduate courses for

future research scientists. Their methods of instruction may vary substantially from faculty whose roles include teaching science to non-science majors or pre-service science teachers. While those distinctions may be recognizable within a culture of scientists, outsiders sometimes have problems distinguishing science researchers who may teach from science teachers who may do research. When natural scientists teach in colleges of education and educators teach within the natural sciences, their colleagues may have even more difficulty understanding differences within the culture of scientists. One-size-fits-all policies for uniform instruction in science either reveal an ignorance of scientific culture, or represent purposeful attempts to deconstruct it. By analogy, landscape arborvitae may thrive in a pot for many years and reach full maturity. By contrast, a Western red cedar (another type of arborvitae) will never reach its potential of 150 feet tall by growing in a pot. Perhaps some policy makers do not want science to have such a high stature in America. Researchers in natural sciences at top-level research (R-1) institutions may think that uniform instructional policies would not apply to them. Maybe they would be correct. Personal experience disagrees with that view.

Attacks upon research and academic scientists by educational researchers, or attempts to gain supremacy in academia through mandates or policy enforcement, by the NSTA, would not bode well for the future of science in America's schools and universities, especially if failed K-12 policies are implemented at the university level. Pedagogy should not try to trump science. National policies at NSF have changed since the Director's Statement in 1957 (NSF, 1958). Opposition to mandates is not as strong as it used to be, and new policies have created problems.

Glaring holes in national policies for laboratories exist within the literature. For instance, Glagovich and Swierczynski (2004) found that both NSF and U.S. Department of Education (DOE) initiatives omitted a well-known occurrence in research laboratories – experimental failure. In what turned out to be a fortuitous study, their graduate students were asked to develop a new “foolproof” undergraduate laboratory to reduce aromatic nitro compounds to amines. The graduate students surveyed the chemical literature and selected 10 different methods, which were approved for testing by faculty. Only one method worked consistently, and met agreed upon criteria for undergraduate laboratory use, such as safety, minimal waste disposal, time to completion, product yield, etc. The student responses to those findings became the basis of the following research report.

According to Glagovich and Swierczynski (2004), the graduate students were amazed that most of the reduction reactions failed when they thought they had replicated the article procedures. Their professors were able to discuss with them some variables, which may have caused failure, and how science is often advanced through the study of those failures. It was determined that, as undergraduates, those graduate students were so accustomed to reactions proceeding in the laboratory as they were taught during lecture, that they had come to assume that by following procedures in published articles, they would be able to yield the same results. Based on those graduate student experiences, professors purposely designed an undergraduate laboratory to include one procedure, which nearly always worked, with several others, which nearly always failed, so undergraduate students would begin to practice learning

from failure earlier in their course of studies. They did not inform the undergraduate students of their purposes for the lab, nor distinguish the “foolproof” procedure from the others. Would professors, mandated to present all laboratory purposes to their students, as NSTA recommended, have been prevented from creating this learning experience?

Cooper and Kerns (2006) designed an open-ended organic chemistry laboratory, where students had to characterize an unknown, then find a nitration procedure in chemical literature and justify using it to the department. In the student experiments, reaction rates varied and some unknowns decomposed. Students were encouraged to discuss possible reasons why their experiments failed and to repeat experiments to test their ideas. The process of combining success in characterizing unknowns with failures in nitration procedures, allowed students to learn that science, as a process, is a combination of successes and failures and learning from either result.

What if policies prevented instructors from purposely setting students up to fail, as the professors in the examples explicitly did? Those examples of planned failure in the laboratory are only indicative of a large complexity of issues, skills and content which scientists, either individually, or as groups of scientists, address within individual science courses and within research laboratories. Scientists change content and procedures based upon observations, evidence and personal experiences, not because a policy requires it.

There is nothing unnatural about resisting change. The challenge is to decide what is important to preserve and what is necessary to change. Researchers in science

education have produced results that can be helpful to university scientists. Whether those findings are accepted or rejected is not simply a matter of quantitative versus qualitative data. Recognizing and acknowledging the independence of scientists, along with their traditions and skepticism, is prerequisite to researchers in science education presenting research scientists with ideas for observation or testing. If the ideas withstand scientific examinations, which the scientific community deems appropriate, they will be evaluated for acceptance or rejection from within.

The science laboratory is a component, not just of a course, but a sequence of courses and additional practices—internships, special projects, conference presentations, employment training, graduate study and research assistantships, junior research positions—which combined, comprise a system for research scientists to train future scientists. The primary reason for a science course to have a laboratory component is for the “active search to increase our understanding” described by Director Waterman (NSF,1958).

Within the natural sciences, there are generally accepted ways of doing research, which are sometimes condensed and over-simplified as “the scientific method” (Bauer, 1994). Nevertheless, most scientific methods describe a systematic procedure for observing, hypothesizing, testing, analyzing and evaluating some aspect of the natural world, which adds to a body of knowledge or explains how something works. Beyond that, scientists strive to be objective, while recognizing limitations, which their own subjectivity imposes. They learn to be skeptical of their own work and that of others, testing data until it withstands scrutiny, instead of rushing to conclusions. The work of



others must be acknowledged, when adapted or cited, and it should be first debated for scientific merit, before entering the unpredictable public arena, where anything can happen. There are ethical standards and prohibited activities, such as tampering with or altering data, with sanctions or expulsion for those violations. Additional mandates or policies are not needed; contrarily they limit academic freedom, impair scientific advancement, could stop it altogether, or reverse it. It happened with Galileo. It could happen again.

## **2.5 The “Concept” Debate**

For several years, since entering the formal classroom as a professor, discussions have been ongoing, with a colleague and mentor, a well-respected senior scientist. The discussions involved whether or not university science students actually learned scientific concepts or learned to conceptualize scientifically. It was questioned whether concepts were some “thing” learned, a process of thinking, or both. The instructor’s role and the students’ responsibilities were also reflected in the discussions, by comparing teaching to learning and asking questions about how the two related to each other.

Over time, the discussions led to one primary concern. Who was responsible if concepts were not learned? Implications that students were not learning scientific concepts came from observations in upper division courses and from questioning research interns. The following are examples of the basis for that concern. While discussing a soil cation exchange project with an upper division student, who had already passed several chemistry courses, he was shown a periodic table and asked to determine the ionic charge of a Group IIA element and compare it to that of a Group IA element. He

could neither relate the group number to valence electrons nor to the Octet Rule. Another student, who was proposing a hydroponic experiment, was asked, “How much more acidic is a solution with a pH of 3, compared to a solution with a pH of 6?” The student responded, “Three times more acidic,” instead of the correct answer of 1000. These concepts had been taught repeatedly in lower division courses, and these students had passed examinations in those courses. Yet, outside of the classroom and course laboratory, these students could neither recall nor properly apply what they had been taught. Were the concepts not properly taught, or were the students not properly learning them, or both?

The examples of students, who had successfully passed examinations in prior semesters, indicated they neither remembered the science concepts as generalizations (acidity, defined as  $\text{pH} = -\log [\text{H}^+]$ ), nor grasped the synthetic processes chemists use to answer questions. Group numbers describe the number of an element’s valence electrons; stable electron configurations and the Octet Rule are used to predict and describe changes in the number of valence electrons and resultant charges for ionizing elements; cation exchange capacity is affected by the number of charges each cation carries. Questions about examinations, as indicators of a student’s future ability to apply concepts, or think synthetically, raised even more questions on how to best determine student learning. Examinations have essentially provided an indication of the student’s ability to recall content at a point in time, within the limited parameters of the examination. When practical application problems arose, which differed only slightly from that which was

taught and tested in the classroom or laboratory, it was unknown whether the graduating student would be able to solve them or not.

A second colleague suggested that misconceptions caused students to think about problems unclearly, or solve them incorrectly (Jessica Thompson, personal communication, June 21, 2005). It was suggested that those misconceptions should be elicited from the students and the fallacies discussed, so students would replace them with scientifically acceptable concepts. After an investigation of peer-reviewed literature for topics related to conceptual change, a qualitative study (Van Doren, 2008) was conducted, that was designed to elicit student misconceptions about motion. The students were shown the flaws in their misconceptions and attempts were made to convince students to abandon them, in favor of scientifically acceptable conceptions. The elicited misconceptions were surprising—in range, unpredictability, incomprehensibility and persistence. In the classroom, once the misconceptions were elicited, scientifically acceptable concepts seemed harder to teach to students, while the elicited misconceptions appeared to strengthen. Students often preferred the misconceptions of their peers to the concepts of recognized experts. They elaborated and added to each other's misconceptions and relished in their knowledge. Test scores plummeted. The research work began and halted several times; the results were incomprehensible. Student self-evaluations soared, as did course evaluations. Students responded well to the participatory process and thought they had learned much; instructor observations and test scores indicated just the opposite.

In a follow-up discussion, my elder mentor indicated that throughout 45 years of teaching, she had never elicited misconceptions from students; her admonishment was that the instructor's role was to always teach and model concepts properly, regardless of learner skill level. If encouraged, students would strengthen their own misconceptions, rather than learn scientifically acceptable concepts.

## **2.6 diSessa's Fault Line: an Ivory Tower Look at “Concept”**

A review of educational literature, spanning five decades (Carey, 2000; diSessa, 2005; Kuhn, 1962; Posner & Strike, 1976; Toulmin, 1972; Wellman & Gellman, 1992), related to conceptual change, represented the search for consensus to one question, "What was a concept?" Research literature provided uses of the term *concept*, which appeared to support a view that *concepts* were like products or something created. Other researchers seemed to use the term for a process of thinking: conceptualization. Often, no definition for the term was provided. Researchers did not agree on the definition(s) for the term *concept*.

A key article, by diSessa (2005), provided by Mark Windschitl, a former doctoral dissertation advisor, at the University of Washington, illuminated this issue. In the article, “A History of Conceptual Change Research, Threads and Fault Lines,” diSessa contrasted two major conceptual change theories within the discipline of education, coherence theory and fragmentation theory, and traced them back to the opposing views of Thomas Kuhn (1962) and Stephen Toulmin (1972). From a study of various educational researchers’ beliefs about concepts, and how those beliefs influenced their research, it appeared there were divergent views among conceptual change researchers.

New terms appeared, which were used in place of the term *concept*. Some researchers used terms like *facets* (Minstrell, 1982) and *p-prims* (diSessa, 1983) as the lower part of a spectrum which progressively led through *nominal facts*, *narratives*, *mental models* until reaching the level of *coordination classes* to which *concepts* belonged (diSessa, 1996; diSessa & Wagner, 2005). Other researchers debated that *concepts* were similar to *beliefs*, yet both were less than *intuitive theories* (diSessa, 2005). Some debated *modes of construal* as “weak theories” (Keil, 1994) or replaced *theories* with *ontologies* (Chi, 1992). Others questioned whether there really was a “fault line” between “theory-theory perspectives” and “knowledge in pieces” perspectives (diSessa, 2005).

## 2.7 Etymology and Definitions of the Term “Concept”

The search term *definition of concept* yielded over nine million links at the Google website, in April of 2008. The first link defined concept as “the general idea behind a slogan, pitch or campaign.” The fifth link, an online version of the Merriam-Webster Dictionary, listed two definitions for the English term *concept*, as a noun and as an adjective (figure 2.1). The etymology indicated that the term came from “Latin *conceptum*, neuter of *conceptus*, past participle of *concipere* to conceive.”

**<sup>1</sup>con·cept** ㉔

Pronunciation: \ˈkän-,sept\

Function: *noun*Etymology: Latin *conceptum*, neuter of *conceptus*, past participle of *concipere* to conceive — more at CONCEIVE

Date: 1556

1 : something conceived in the mind : THOUGHT, NOTION 2 : an abstract or generic idea generalized from particular instances**synonyms** see IDEA**<sup>2</sup>concept**Function: *adjective*

Date: 1896

1 : organized around a main idea or theme <a *concept* album> 2 : created to illustrate a concept <a *concept* car>Figure 2.1 Merriam-Webster Online Definitions for the Term *Concept*.

A discussion with a Latin professor (Mary Alice Muellerleile, personal communication, April 4, 2008) revealed that the dictionary had provided an inaccurate translation. Conceive/conceived were not the most appropriate English words to describe those Latin terms. In Latin, *Concipo* was a present stem verb, translated directly *I-with-seize* or *I-with-take*. A clearer translation could have been *I seize together*. *Concipere*, an infinitive stem, meant *(to) seize together/take together*. *Concepta*, *conceptus*, and *conceptum* were feminine, masculine and neuter past participles for *seized together/taken together*. Merriam-Webster Online provided no explanations for the use of conceive/conceived instead of seize/seized or take/took in the translation. This distinction in meaning between *conceived* and *taken together* paralleled the academic distinctions between the coherence theorists and fragmentation theorists.

Why the Latin verbs and past participles became English nouns and adjectives was unknown. Latin *Conceptum* and *concupere* had become, in the English term *concept*, a thing, real or abstract (noun), or an attribute of a thing (adjective) rather than the actions and states of being the Latin words conveyed. Even in modern English, “conceived” was not the same as “something conceived.” No explanation for the change from the Latin verb to English noun was given in the Merriam-Webster Online dictionary.

Webster’s Revised Unabridged Dictionary (Concept, n.d.) also attributed the etymology of the term *concept* to the aforementioned Latin terms, but provided an additional linkage of the term to the French past participle, nominative *conciez*. *Conciez*, translated as *conceived* in current English, was once translated into English as the term *conceit* (Concept, n.d.). For some time, *conceit* and *concept* were used similarly, in

English, but their roots conveyed different meanings. They were not exactly equivalent. While the use of the term *conceit* for *concept* diminished, the term *concept* acquired the attributes of the French *concevez* (conceived) and lost the attributes of the Latin *conceptum* (seized together). An English professor described the process, which allowed the meaning of one term to become the meaning of another term, as transference (Dr. Loren Schmidt, personal communication, April 11, 2008), suggesting it that had something to do with Viking-subdued Norman (French) Anglo-Saxon invaders, in turn, subduing the Romano-British (Latin-Welsh-Gaelic) and imposing more foreign languages upon them. The English language, thus influenced, has continually changed; few who use it study the history of the words they speak or write. A dictionary of literary terms (Conceit, n.d.) also described the change in meaning of the term *conceit* after the transference of its original meaning to *concept*:

Before the beginning of the seventeenth century, the term *conceit* was a synonym for "thought" and roughly equivalent to "idea" or "concept." It gradually came to denote a fanciful idea or a particularly clever remark. In literary terms, the word denotes a fairly elaborate figure of speech (para. 1).

Thus, the meaning of *conceit* and the meaning of *concept* had both changed. No other dictionary explanations were found for the change in meaning of the English term *concept*, other than the references to different etymology and those provided by the Latin professor. While not explanatory, additional evidence for gradual change in the English meaning of the term *concept* was found in the Oxford English Dictionary Online (Concept, n.d.):



1566-7 PAINTER *Pal. Please*. I. 33 Being in this louing concept, hee extolled the prayse of his wife to one of his garde.

1571 GOLDING *Calvin on Ps. lxxiii*. 20 We forge fantasticall toyes in our own concepts.

1663 G. HARVEY *New Philos*. I. 66 Oviedo makes it a great difficulty to distinguish the concept of Peter and horse.

1837-8 Sir W. Hamilton *Logic* viii. (1859) I. 134 The concept *horse*...cannot, if it remain a concept, that is a universal attribution, be represented in imagination.

*Ibid.* xv. (1866) I. 275 Concepts are merely the results, rendered permanent by language, of a previous process of comparison.

These quotes show that the Latin past participle gradually changed *Being in this louing concept* to a noun in *Concepts are merely the results*, over a relatively short period of time. Evidence that the term *concept* was also part of Old English and how the English forms waned in use was found in the Oxford English Dictionary Online (*concept*, n.d.):

1706 PHILLIPS (ed. Kersey), *Concept*, a set Form; a term used in Publick Acts.

1921 E. Sapir *Language* ii. 28 Ever since the breakdown of the English forms that set in about the time of the Norman Conquest, our language has been straining towards the creation of simple concept-words.

1923 J.S. Huxley *Ess. Biologist* i. 25 the attainment of the power of generalization—of reason, concept-formation, or what you will.

1938 *Mod. Lang. Rev.* Oct. 555 this concept-chasing is a consequence of the more or less arbitrary ‘periodization’ of literary history.

In the educational references reviewed, few of them defined the term *concept*. Two examples have been provided in this section, one from coherence theorist Susan Carey, and another from fragmentation theorist Stephen Toulmin. Further uses of the term *concept*, in relation to other terms specific to either coherence theory or fragmentation theory, have been provided in the respective coherence and fragmentation sections.

Susan Carey (2000) discussed concepts as entities having core and peripheral features. Carey used the modern definition of *concept* as a noun. She distinguished between what entities looked/sounded/felt like (perceptual) and what entities were (their core features):

The core of the concept includes its causally deepest properties, those properties that determine what kind of thing the entity is and its particular properties....Core properties, or essential properties, are often not perceptually available....If concepts' cores include nonobservable causal constructs, then concepts that have cores have a nonperceptual component....The attribution of causality goes beyond spatiotemporal analysis. (p. 38)

Carey also claimed that beliefs were relational entities. Beliefs related two or more concepts together; changing beliefs was easy but changing the concepts, which made up the beliefs, was difficult (Carey, 1985). Stephen Toulmin (1972) asked two questions before he provided a definition of the term *concept* in a third question:

What is Man that he may understand the World? And what is the World that Man may understand it? In particular, so as to focus on the central element in human understanding, we must ask: What are the skills or traditions, the activities,

procedures, or instruments of Man's intellectual life and imagination—in a word the *concepts*—through which that human understanding is achieved and expressed? (p. 11)

## 2.8 Coherence Theory

Andrea diSessa (2005) stated that for many, Thomas Kuhn “defines the enduring relevance of the history of science to studies of conceptual change broadly” (p. 268). diSessa then cited evidence of strong contemporary opposition to Kuhn's views (Toulmin, 1972) and later included some of his own articles (diSessa, 1996; diSessa & Wagner, 2005). Since diSessa supported the opposing view, the author decided to review Kuhn's (1962) original works and those of a few of his successors, in this literature subset. Toulmin and diSessa are reviewed separately in the fragmentation theory literature discussion below (section 2.9).

Kuhn (1962) researched the history of science and described a dichotomy in which once accepted, but out-of-date beliefs either had to be described as myths or as incompatible theories which were “not in principle unscientific because they have been discarded” (p. 3). Choosing the latter, Kuhn described a process of “normal science” in which scientists performed their work on the assumption they knew what the world was like (p. 5) and only changed their view when “incommensurable ways of seeing the world” (p. 4) and “anomalies that subvert the existing tradition of scientific practice” brought about “extraordinary episodes” and “scientific revolutions” (p. 6).

Kuhn (1962) considered normal science to mean that a group of scientists based their research upon mutual acceptance of some past achievements, which was usually

kept in textbooks. If achievements were significant enough to attract adherents away from another “competing mode of scientific activity” and if the achievement left enough problems for the adherents to address, a new “paradigm” was created (Kuhn, 1962 p. 10). Kuhn claimed this was necessary because the absence of a paradigm would make all possible pertinent facts to a developing science equally relevant (p. 15); a “body of belief” (p.17) had to be present:

To be accepted as a paradigm, a theory must seem better than its competitors, but it need not, and in fact never does, explain all the facts with which it can be confronted. (p.17)

Kuhn did not believe that concepts, laws and theories could be learned “in the abstract and by themselves” but rather through “professional initiation” (pp. 46-47). Terms like *force* are not learned from definitions; meaning, if ever discovered, was said to have come from “observing and participating in the application of these concepts to problem-solution” (Kuhn, 1962, p. 47). As long as the problems continued to be solved, the paradigm was not challenged.

In order for a new theory and subsequent paradigm to arise, a crisis had to occur (Kuhn, 1962). This crisis was precipitated by a “pronounced failure in the normal problem-solving activity” (pp. 74-77). At this time, alternatives were studied; a scientific theory could only be rejected if an alternate candidate was available to take its place. Kuhn claimed that these paradigms were not just compared with nature, but with each other.

Kuhn (1962) believed that a crisis-caused transition from one paradigm to another was not a cumulative process, but a reconstruction. Goals, methods, and views all would have changed in the new paradigm, as if “picking up the other end of the stick” (Kuhn, 1962, p. 85). Kuhn compared this to gestalt; new paradigms were said to have “redefined science” or even to have “old problems relegated to another science or declared entirely ‘unscientific’” (p. 102). Kuhn further claimed that while new paradigms borrowed vocabulary from old ones, they “seldom employ these borrowed elements in quite the traditional way” (p. 148). Therefore, communication between different paradigms was only partial. Kuhn concluded that proponents of different paradigms “practice their trades in different worlds” (p. 149).

Wellman and Gelman (1992) provided a link from the time of Kuhn to that of diSessa. diSessa's (2005) ‘threads’ described the branching development of Kuhn’s (1962) coherence theory into paradigms of naïve theories (Carey, 1985), which compared the development of student ideas with Kuhn’s history of science, and “theory theory” (McCloskey, 1983), which claimed that students have theories analogous to scientists’ theories:

Common sense theories are nonscientists’ everyday understandings of certain bodies of information such as folk zoology or naïve astronomy. Various serious claims have been advanced: that human concepts are entrenched in larger naïve theories; that conceptual change and thus important aspects of cognitive development are akin to theory change in science; that cultural world views are instantiated in folk theories; and that theories supplant similarity-based

conceptions both in current scientific thinking and in the individual's own learning or development (McCloskey, 1983, cited in diSessa, 2005, p. 271).

Posner and Strike (1976) published an article, which described content sequencing principles as a set of concepts, which were "tools of thought" (p. 683). Posner and Strike worked with other researchers to develop these tools into the rational model of Posner, Strike, Hewson and Gertzog (1982), as described by diSessa (2005). This early work with rational models supported the coherence theory paradigm in that students and scientists alike "maintain current ideas unless there are good (rational) reasons to abandon them" (diSessa, 2005, p. 271).

## **2.9 Fragmentation Theory**

Andrea diSessa (2005), described the field of research in conceptual change as consisting of "multiple perspectives that combine many commonsense and theoretical ideas in kaleidoscopic fashion" (p. 271). diSessa ascribed the beginnings of fragmentation theory to Toulmin's rejection of coherence theory. Toulmin (1972) distinguished thoughts from concepts: "Each of us thinks his own thoughts; our concepts we share with our fellow-men" (p. 35). Toulmin viewed "thoughts and beliefs" as "personal and individual" while concepts were "communal and collective" (pp. 35-37) and compressed it into "a single epigram: every concept is an intellectual micro-institution" (p. 166). Toulmin went on to make a major point; he claimed that scientific disciplines were more than individual concepts, or even sets of concepts. In this view, concepts had a relationship to disciplines similarly as individuals did with societies.

Toulmin (1972) claimed that Kuhn's work was based upon unanswered questions of an earlier researcher, R.G. Collingwood (1956); the work was so similar "that a glossary can be established for translating between them" (Toulmin, 1972, p. 99).

Toulmin disagreed with the relativistic implications in the theories of Collingwood and Kuhn. Toulmin (1972) stated those implications as

a Newthinker and an Oldthinker have no common vocabulary for comparing the rational claims of their respective theoretical positions. . . . The merits of intellectual 'revolutions' cannot be discussed or justified in rational terms—since no common set of procedures for judging this rationality are acceptable, or even intelligible, to both sides of the dispute. . . . Only after the victorious new paradigm is securely enthroned in acknowledged power can the rule of rationality be restored. . . . New frameworks of fundamental theory cannot themselves be arrived at in a 'rational' or 'rule-following' manner. Paradigms are sovereign; they make their own laws. (p. 102)

Toulmin (1972) argued against Kuhn for several pages of his book, accusing Kuhn of misusing words and changing definitions between the 1962 and 1970 editions of his own book. He wrote that Kuhn's use of the term revolution was an exaggeration in that "underlying continuities on a methodological level were concealed by the intellectual discontinuities on a theoretical level" (Toulmin, 1972, p. 105) and that the doctrine of paradigms originally had nothing to do with revolutionary paradigm-switches. Toulmin traced the origin of the term *paradigm* to the German term *paradeigma*, attributed to Georg Christoph Lichtenberg, who modified the Latin term *paradeigmata*, a standard

related to fundamental patterns of explanation. Toulmin summarized Lichtenberg's definition as "we explain puzzling phenomena by relating them to some standard form of process, or paradigm, which we are prepared to accept for the moment as self-explanatory" (p. 106). Toulmin claimed that, prior to Kuhn, the term *paradigm* was never used to imply that changes occurred "in an abrupt, discontinuous, or 'revolutionary' manner" (p. 107) and that Kuhn's theory of scientific revolutions (later called coherence theory) must be separated from any theory of paradigms.

Toulmin (1972) claimed it was a mistake to assume that a natural science must be viewed as an entirely coherent logical system. Toulmin stated that "systematically related concepts and procedures" coexisted with others "which are logically independent of, and even at variance with, one another" (p. 128), and that it was also a mistake for sociologists to assume that "society as a whole forms a single coherent and functional 'social system'" (p. 129). His main point was that both science and societal institutions were "related more loosely than has recently been assumed" (Toulmin, 1972, p. 130).

How an apprentice scientist grasped science concepts from a previous generation, was termed 'enculturation' (Toulmin, 1972, p. 159). This was a process by which explanatory skills were transferred to the next generation. The 'thing' learned was comprised of "intellectual techniques, procedures, skills, and methods of representation" for "giving explanations of events and phenomena within the scope of the science concerned" (Toulmin, 1972, p. 159).

In his conclusion, Toulmin (1972) wrestled with empirical and relativistic views of science:



By allowing each separate culture and epoch to decide, by its own standards, what properly counts as ‘scientific understanding’ (or ‘technical efficiency,’ or ‘justice’) we plunge ourselves back into relativism; once that is done, the very question, whether some new set of concepts promotes the fundamental goals of ‘scientific understanding properly so-called,’ will be understood in quite different senses in different milieus, and answered in correspondingly independent ways. By imposing universal, abstract definitions of the ‘scientific; and the ‘legal’ from outside, we land ourselves equally in an arbitrary absolutism; once that is done, we are laying down *a priori* standards of rationality for anything we shall acknowledge as (say) ‘science’ or ‘law’ in advance of any consideration of the actual diversity to be found in those enterprises. . . . From what source do they derive their supposedly universal authority? (p. 496)

Toulmin desired to find a middle ground between absolutist and relativistic extremes, and he urged people not to substitute formal dialectic for fundamental substantive questions. Neither formal definitions nor analytical dialectic could achieve the “impartial rational standpoint” he advocated, which included accumulated experiences of “...all cultures and historical periods” (Toulmin, 1972, pp. 497-500). Toulmin stated that “rationality then consists in the fundamental obligation to continue reappraising our strategies in the light of fresh experience” (p. 500).

diSessa (2005) stated that he and Minstrell (1982) supported Toulmin’s critique of coherence theory and were the early advocates of fragmentation theory, sometimes known as “knowledge in pieces” (diSessa, 2005, p. 273). Hunt and Minstrell (1994)

developed theories that “facets” were “elemental and instructionally relevant ideas students have upon entering instruction” (as cited in diSessa, 2005, p.273) and their equivalent “P-prims” (diSessa, 1983; cited in diSessa, 2005, p.274), “explanatorily primitive elements” need “reweaving into a different, stronger, and more normative conceptual fabric” (diSessa, 2005, p. 273).

Modern fragmentation theorists usually developed their own terms for their constructs, and provided their own models and definitions rather than using existing terms such as *concept*, and *theory* (diSessa, 2005), yet the term *concept* still appeared in many of their statements. Central to fragmentation theory was the idea that most learners did not have strong, coherent theories, naïve or otherwise; their knowledge was not yet put together in a manner which would result in “distinct knowledge in different circumstances,” ensuring “that the concept works in functionally the same way in different contexts” (diSessa, 2005, p. 276). In this instance, diSessa (2005) used the term *concept* as a ‘coordination class,’ defined as “an explicit model of a certain kind of concept” (p. 275). diSessa then stated “few explicit models of coherence exist” as an argument favoring fragmentation theory over coherence theory, but tempered the statement with “No one thinks children are completely unsystematic in their thinking about domains” (p. 277). Rather, diSessa (2005) claimed that systematicity (coherence) was the emergent result of knowledge in pieces theory.

Pieces of both Kuhn’s and Toulmin’s theories survive within teacher preparation programs. The doctrine of paradigms is quite popular, though few know of its origin. It is used to support the relativistic ideas of post-modern philosophies and to delegitimize

theories with which one may disagree. Toulmin's ideas are used to support developmental learning theories which emphasize the important central role of teachers in a slow, determined, progressive knowledge assembly process, within a lengthy preK-16 school system. Unfortunately, academic discourse has become distorted and morphed into a tool to support socio-political education agendas.

## 2.10 Summary

For whom the bell will toll, within the ivory towers, remains to be seen. It is becoming clear that science education, if led by academics, will never wander far from the shelter of the formal classroom or laboratory. The NSF-ISE initiative is currently academically self-absorbed and will have only occasional community impact. The SENCER initiative continues to focus educational relationships on communities being included in university courses. At least SENCER is trying to decide how to take science into the community, not just training a few experts, but interacting more closely with local communities, valuing the people's knowledge as much as academic knowledge.

Sophistry is still despised by people with common sense. Attempts to re-define science or rigidly mandate what scientists do should be challenged as an attempt to attain ideological, financial and political power. Technological societies require science for survival. Groups like the NSTA want to be gatekeepers for all preK-16 science education and claim their pedagogy trumps all others, similar to university accreditation.

The etymological reviews of the terms *science* and *concept* pointed out some tendencies in academic discourse towards esoteric arguments. The etymology and changing meanings of the term *concept*, over time, indicated the transference of meaning

from one term to another. The development of two diverging theories about conceptual change revealed that coherence theorists, such as Kuhn, needed paradigm revolutions, to subsequently redefine terms like *concept* after each revolution. Fragmentation theorists, who built their theories upon Toulmin's refutation of coherence theory, constructed other definitions and new models, redefined the term *concept* and claimed that coherence was the result of assembling knowledge from pieces—back into *concepts* and other terms.

Neither formal definitions nor analytical dialectic will achieve an “impartial rational standpoint,” if the accumulated experiences of “all cultures and historical periods” are ignored (Toulmin, 1972, p. 500). This chapter has exposed a current mindset that science education must originate from, and be directed from within ivory towers to be valued. There are people who disagree with that premise, who argue the value of community discovery and knowledge. Other cultures have viewed learning, including science, differently. Those views may help in an attempt to balance analytical dialectic with other ways of knowing, as discussed in the next chapter.

## **Chapter 3**

### **Real Worlds, Real Languages, and Informal Science Education**

#### **3.1 Introduction**

Words without action and forgotten writings have been around for a long time, but they are ubiquitous today. Some people do not stand behind their words; cheap talk (words without action, lies, or broken promises) is common. For any culture, which relies heavily upon oral histories and verbal agreements, these words without action are disconcerting. Many written words have been buried (Remus, 1977) in mountains of publications—and forgotten—while some oral histories have survived millennia (Yakama legends of ice-age floods). The previous chapter discussed how changes in word meaning influenced learning theories within the English language. Native American cultures and languages influence worldviews and science learning in ways usually overlooked by Western scientists.

In chapter 2, coherence theory (Kuhn, 1962) and fragmentation theory (Toulmin, 1972) were described as diverging conceptual change theories, with fault lines (diSessa, 2005) separating them. Those debates represented deconstruction and synthesis processes in Western thought that fit well within an isolating (or analytical) language such as English, where each word has few morphemes. In this chapter, some Native American learning theories are introduced, which differ from both coherence and fragmentation conceptual change theories. Native American ideas have been difficult to communicate, not only because of wide differences between synthetic Native languages and English but also because Native languages are languages of place. Since Native languages are place-

based, this chapter develops additional rationales for place-based science education, particularly informal science education.

Native American colleagues pointed out the references cited in this chapter, unsolicited. Without their guidance, the research path would have been different from this attempt to illustrate that differences in worldviews are affected by two major influences: how people view themselves in the world and how their language describes that relationship.

### **3.2 Language and Assimilation Impacts Upon Native American Knowledge**

In ancient times (both in myth and history), many generations of people passed knowledge to younger generations through spoken words, stories, songs and prayers. Leaders probably chose their words of instruction carefully and verified that they were repeated and retold accurately. Promises and vows, made verbally, were followed by actions, which “amounted to something” (Joseph, 1879). The knowledge of entire cultures sometimes relied upon good words and the ability of people to remember and act upon them. Stories about times when people could remember spoken words, without the need to write them down or read them, are found throughout cultures around the world.

A Native American story (Navajo) described a powerful being that created with its voice; then it gave language to humans. People, in turn, were allowed some level of participation in acts of creation. In the book *Native Science*, Gregory Cajete (2000) described a story of Sotoknang, who formed Spider Woman. Spider Woman created the natural world, including humans, but it was Sotoknang, the nephew of the infinite Taiowa, who gave them speech (Cajete, 2000, p. 32). Similarly, in the Bible, The Word,

the Son of God, created all things with His voice (John 1:1-15, Psalm 33:6). For the first human task, God had all the other creatures brought to man, because He was curious to see what man would name them (Genesis 2:19).

Writing came later. That became a problem, according to stories, because people remembered little of what they read. Two examples are the myth of Thoth, who was chastised for giving writing to humans (Plato's *Phaedrus*), and the efforts of the Biblical Moses, who repeatedly had to speak, write and read commandments to the Israelites (Book of Exodus). In those stories, forgetfulness was associated with written words.

Through the English language, came a severe disruption of traditional methods of knowledge transfer within Native American cultures. In America, both spoken and written treaties were made (in English) with Native American tribes—and broken. The Euro-Americans, who made the treaties, ignored their own words. Wars were fought. Native cultures were decimated. Afterward, Western culture's insistence upon spoken and written English, through assimilation policies, caused many Native American oral traditions to be lost. Children were forcefully separated from their parents and culture. They were taken from their homes and placed in boarding schools, where they were forbidden to speak their own language, to wear traditional dress, or to practice tribal customs. Removed from their sense of place, language and familiar traditions, some children assimilated into Western culture, and some were forced to become servants. Others returned home after schooling to find out they had changed from their relatives. Some strived to learn oral traditions and language from their elders, but older generations passed away before all knowledge could be transmitted. The traditional pattern of

generational knowledge transfer was nearly broken.

Those memories of assimilation policies remain strong among Native American communities and are reason enough for their distrust of Western culture, especially compulsory education. Concurrently, growth in government has led to increasing regulations in other areas of Native American life, affecting hunting, fishing and traditional activities, both on and off reservations. Furthermore, some science educators, in their zeal to put forth ideas to “help” communities or make amends for past events, have hastened to implement science education reforms, ignoring scientific debate and Native Science ideas alike. It should not be surprising that some communities have chosen to rebuild their own culture, without outsiders “fixing” it for them. Centralized science education efforts, whether formal or informal in nature, are perpetual reminders of Western assimilation policies.

Guthrie (2007) offered another perspective to the American conquest and its impact upon Native Americans. His paper concluded “that the conflict, which was not just a political and military struggle over land driven by ideas about race and civilization but also a complex discursive encounter in which language ideologies played a powerful role” (Guthrie, 2007, p. XX). Guthrie also claimed, “One important effect of the language ideologies I have described was that Euro-Americans were able to dismiss Indian speech as metaphorical, poetic, and pathetic rather than legitimately political” (p. XX). Native American languages were central to their culture. Political ideologies have underpinned Indian assimilation policies, academic discourse and science teaching policies. They have left a trail of destroyed cultures, which were all dismissed as pathetic.



### 3.3 Native Languages, Native Science and Place

Often, Native American ideas have been difficult to communicate because of wide differences between Native languages and English. Native languages are also languages of place. Witherspoon and Peterson (1995) documented how Navajo language is deeply connected to the physical landscape of their homeland, their art, customs, worldview and cosmology. One word, *hózhó*, encompasses many ideas: holism, beauty, harmony and well-being only begin to describe it (Witherspoon & Peterson, 1995, p. 14). The Navajo language impacts the daily lives of the people who speak it. They believe that Holy People sang their world into existence, and this one word is the most important in their language (pp. 16-17).

Likewise, Angayuqaq Oscar Kawagley, an Alaskan Native, provided numerous details about the Yupiaq worldview (Kawagley, 1995), which have emphasized the importance of place, language and experiences upon worldview. “For the Yupiaq people, culture, knowing and living are intricately interrelated” (p. 73). Like the Navajo, the Yupiaq language has certain words of great importance. For the Yupiaq, *ella* is a word, which when modified in speech, “epitomizes the philosophy of the Yupiat” (p. 73). It can mean anything from awareness, to weather, to Creative Force, to the universe (Kawagley, 1995).

Unlike the etymological study of the English term *concept*, earlier in this thesis, which revealed changes in meaning from superimposed languages, changes from verb and adverb to noun and adjective, and changes in term redefinition by academic scholars, the Native terms, briefly discussed here, have extremely complex uses and meaning.

Their meaning can only be understood in their own languages, languages reflecting the holistic philosophies of the people who speak them. Others (Cajete, 2000; Witherspoon & Peterson, 1995) have strongly argued that holistic ideas are poorly understood in the analytical language of English and in Western philosophies of science.

Gregory Cajete (2000) claimed that a dysfunctional cosmology, in which humans perceived of the world as material property, without life or spirit, not only resulted in the domination of Indigenous peoples, but has caused “ambiguity, conflict and tension . . . at all levels of modern life . . .” (p. 53). Cajete also claimed “until recently, the power of language to condition thought either toward participation with nature or away from it has been largely ignored” (p. 28). Central to his idea is the metaphoric mind, which “relates to the world in the more holistic structures of oral stories, linguistic metaphors, images and intuitions” (p. 29). This metaphoric mind of nature has been subdued by the younger, rational mind of language, but still manages to surface through “abstract symbols, visual/spatial reasoning, sound, kinesthetic expression, and various forms of ecological and integrative thinking” (p.30). Cajete concluded

Because Native science is thoroughly wrapped in a blanket of metaphor, expressed in story, art, community, dance, song, ritual, astronomical knowledge, and technologies such as hunting, fishing, farming, or healing, rationalistic scientists, its “younger brothers,” have difficulty understanding its essence of creative participation with nature. (p. 30)

Witherspoon and Peterson (1995) wrote that in a Western worldview “the ontological focus has been on the fundamental and smallest building blocks of the

universe that can be isolated” (Witherspoon & Peterson, 1995, p. 7). Those dissection and building processes have dominated Western learning theories and are influenced by the analytical structure of English language. Western science has reduced humans to cells, to DNA, to base pairs, to atoms and electrical potentials. The entire world has been reduced to chemical elements, to subatomic particles and pure energy. After the world was reduced, Western science has embarked on a conceptual re-synthesis process, such as earth system science. Some Western physicists have favored open construction: string theory and hyper-dimensional physics proposed multiple universes, multiple paths in space-time, parallel worlds, where anything was/is possible, where place-based concepts of reality are constantly challenged. Others, such as geologists have created extensive linear timelines, purporting to explain how everything came to be, remarking, as the late Walter Cronkite once said each night, “And that’s the way it is,” followed by the date.

The conceptual change theories of Kuhn (1962), Toulmin (1972) and diSessa (2005), as presented in Chapter 2, stated that knowledge must either be continually deconstructed and rebuilt – “a crisis-caused transition from one paradigm to another was not a cumulative process, but a reconstruction” (Kuhn, 1962, p. 84) – or that knowledge must be built from scratch: “most learners did not have strong, coherent theories, naïve or otherwise; their knowledge was not yet put together . . .” (diSessa, 2005, p. 276). Native American worldviews, as presented by Cajete (2000), Kawagley (1999), Witherspoon and Peterson (1995), suggest that those theories are incomplete, that they focus too much on parts, rather than a whole. They suggest that language has much to do with those worldviews. Witherspoon and Peterson (1995) wrote:

The Navajo passion for integration, synthesis, and assimilation of diverse elements into a holistic pattern or structure is likely related to the absorbent nature of the Navajo verb. If this is true, it is an element they must share with other Athabascan speakers because this absorbent verbal pattern is shared with all of them. This means that this passion for synthesis is a very ancient tradition among Athabascan speakers, but this does not mean that it is necessarily given the same meaning, expression, or prominence in every contemporary Athabascan community.

Navajo world view focuses on holistic patterns, and this holistic emphasis generates, in part at least, the Navajo passion for synthesis. To be Navajo in outlook and practice is to look for holistic essence. Although the Navajo recognize the existence and even the structural necessity for disorder (*hochó*) they cannot tolerate disorder for long periods of time. To them, it is sickness—illness in both the mind and body, fragmentation in the environment and in the universe, disharmony in customary relationships and holistic schemes. When it occurs, *hózhó*—holism, health and harmony—must be renewed, regenerated, or restored. That is the purpose of prayer, ritual, ceremony, myth, song and art. (Witherspoon & Peterson, 1995, p. 21)

### **3.4 A Voice From History**

On January 14, 1879, while visiting Washington D.C, a Wal-lam-wat-kain, Chief of the Chute-palu, otherwise known as Chief Joseph, of the Nez Perce, stood to speak in Lincoln Hall. What was actually said is probably not what has been recorded. Guthrie's

(2007) research provided considerable doubt as to the transparency and completeness of the printed speech. Yet, some of Chief Joseph's voice likely survived the language ideology and politics of conflict of the late 1800's. Since very few Native American speeches have been recorded, a large part of it is presented here, to illustrate differences in worldviews, and to imply that educational policies of a dominant culture could impede indigenous people's learning:

At last I was granted permission to come to Washington and bring my friend Yellow Bull and our interpreter with me. I am glad I came. I have shaken hands with a good many friends, but there are some things I want to know which no one seems able to explain. I cannot understand how the Government sends a man out to fight us, as it did General Miles, and then breaks his word. Such a government has something wrong about it. I cannot understand why so many chiefs are allowed to talk so many different ways, and promise so many different things. I have seen the Great Father Chief [President Hayes]; the Next Great Chief [Secretary of the Interior]; the Commissioner Chief; the Law Chief; and many other law chiefs [Congressmen] and they all say they are my friends, and that I shall have justice, but while all their mouths talk right I do not understand why nothing is done for my people. I have heard talk and talk but nothing is done.

Good words do not last long unless they amount to something. Words do not pay for my dead people. They do not pay for my country now overrun by white men. They do not protect my father's grave. They do not pay for my horses and cattle. Good words do not give me back my children. Good words will not

make good the promise of your war chief, General Miles. Good words will not give my people a home where they can live in peace and take care of themselves. I am tired of talk that comes to nothing. It makes my heart sick when I remember all the good words and all the broken promises. There has been too much talking by men who had no right to talk. Too many misinterpretations have been made; too many misunderstandings have come up between the white men and the Indians. If the white man wants to live in peace with the Indian he can live in peace. There need be no trouble. Treat all men alike. Give them the same laws. Give them all an even chance to live and grow. All men were made by the same Great Spirit Chief. They are all brothers. The earth is the mother of all people, and all people should have equal rights upon it. You might as well expect all rivers to run backward as that any man who was born a free man should be contented penned up and denied liberty to go where he pleases. If you tie a horse to a stake, do you expect he will grow fat? If you pen an Indian up on a small spot of earth and compel him to stay there, he will not be contented nor will he grow and prosper. I have asked some of the Great White Chiefs where they get their authority to say to the Indian that he shall stay in one place, while he sees white men going where they please. They cannot tell me.

I only ask of the Government to be treated as all other men are treated. If I cannot go to my own home, let me have a home in a country where my people will not die so fast. I would like to go to Bitter Root Valley. There my people would be happy; where they are now they are dying. Three have died since I left

my camp to come to Washington.

When I think of our condition, my heart is heavy. I see men of my own race treated as outlaws and driven from country to country, or shot down like animals. I know that my race must change. We cannot hold our own with the white men as we are. We only ask an even chance to live as other men live. We ask to be recognized as men. We ask that the same law shall work alike on all men. If an Indian breaks the law, punish him by the law. If a white man breaks the law, punish him also.

Let me be a free man, free to travel, free to stop, free to work, free to trade where I choose, free to choose my own teachers, free to follow the religion of my fathers, free to talk, think and act for myself -- and I will obey every law or submit to the penalty.

Whenever the white man treats the Indian as they treat each other then we shall have no more wars. We shall be all alike -- brothers of one father and mother, with one sky above us and one country around us and one government for all. Then the Great Spirit Chief who rules above will smile upon this land and send rain to wash out the bloody spots made by brothers' hands upon the face of the earth. For this time the Indian race is waiting and praying. I hope no more groans of wounded men and women will ever go to the ear of the Great Spirit Chief above, and that all people may be one people.

Hin-mah-too-yah-lat-kekht has spoken for his people. (Joseph, 1879, pp. 412-33)

What can be interpreted from this speech? Chief Joseph intended to be heard that day, in

another language, to ask for the respect that all creatures deserved to have in his worldview of a holistic earth system. In his experience, too many people had not backed their “good words” with honorable actions, repeatedly breaking promises to his people. Decimated by war and disease, forcefully removed from their homeland and detained on small foreign reservation lands, he compared his people’s penned existence with horses tied to a stake; their lack of growth and prosperity due to government denial of their unalienable right to liberty. Unable to choose their own teachers, to practice the religion of their fathers, or to speak their own place-based language, Chief Joseph’s band represents an archetype for any group of people who challenge the presumption of others to determine how they should learn, what they should learn, and where they should learn.

### **3.5 Summary**

Language ideologies played a significant role in the disruption of traditional Native American ways of knowing, sometimes called Native Science. Major differences between analytical English and synthetic Native American languages are mirrored in their differing philosophies. Western Science and philosophies are reductionist, with an analytical (isolating) language that allows the world to be deconstructed and re-synthesized through coherence or fragmentation conceptual change theories.

Alternatively, holistic worldviews are favored by synthetic languages, which have multiple morphemes for each word. Native Science comprises knowledge, including some aspects of Western Science, yet because of different philosophies, it includes spiritual and traditional knowledge, which are not considered part of Western Science.

Western education, as viewed by many Native Americans, is a constant reminder



of systematic attempts to destroy their languages and culture; strong memories of the assimilation policies at Indian boarding schools remain. Native American languages are languages of place. Native writers have suggested that their languages and other ways of knowing, their experiences and the activities of people in their own place—all offer opportunities for science learning; learning which lectures, books and university classrooms are incapable of teaching. Politicized ideologies in Western education, as secular knowledge, are destroying more than just Native American cultures. Facing these challenges in science education and searching for solutions and collaborations between universities and rural Native American communities, which might find ways to integrate Western and Native Science, is discussed in the next chapter.

## **Chapter 4**

### **NSF-SENCER and Native Science Education**

#### **4.1 Introduction**

The National Science Foundation (NSF) was not heavily involved in science education in the 1950s, or early 1960s. Their primary agency focus was on basic research. In recent years, the NSF has solicited proposals for much more than basic research. Proposals for research in science education have been funded. Through the Course, Curriculum and Laboratory Improvement (CCLI) program, universities have received major equipment, laboratory upgrades and funds to develop new courses. The NSF Division of Undergraduate Education (DUE) has issued grants to increase the professional workforce in science through programs such as the Science Talent Expansion Program (STEP) and the short-term community science education projects of the Informal Science Education (ISE) initiative. The Science Education for New Civic Engagement and Responsibility (SENCER) initiative was designed for university science students to engage their local communities with science to address a major issue of importance to both scientists and the community—AIDS, nuclear waste, groundwater contamination, etc.

The SENCER approach includes several components related to engagement by informal activity. First, for students and faculty who are unaccustomed to working and studying outside of the science classroom or laboratory, the community interaction lets them see firsthand that substantial science learning is going on outside of school. Second, they begin to see differences in values between community and university members and

how the processes of science are affected by those differing values. Ideas are not always linked to practice inside the ivory towers. Just as field trials and large-scale farming often do not produce the same results as greenhouse trials, university science sinks or swims in a public sea of ideas. Third, when a community concern is addressed, when university faculty, students and community work together, they share in the success, or failure, of the investigative process and the knowledge generated. Even in failures, the process of working together often leads to renewed efforts to find another solution – or to ask another question.

When communities work together with university scientists and students, bonds are strengthened, between community and university. When SENCER projects reach diverse audiences, there is more community interest and support for schools and for the study of science, in school and out of school. By reaching out, SENCER has engaged communities and impacted diversity within university classrooms.

#### **4.2 Native Science Education: Project Idea**

As an area extension agronomist, in the 1980s, most of my time was spent merging education with work experiences to collaborate with farmers. Discrepancies between the goals of the university and the needs of rural constituents were just beginning to become apparent. Bennett's levels of criteria for evaluating programs (Bennett, 1976; Figure 4.1) were largely ignored by administrators, in that *practice change* and *end results*, levels 6 and 7 respectively, were expected of extension agents with minimal *inputs*, *activities* or *people involvement* – levels 1-3! Emphasis was upon *KASA (Knowledge, Attitudes, Skills and Aspirations) change*, level 5, but little attention

was paid to people's *reactions*, level 4. In essence, the criteria were all jumbled up.

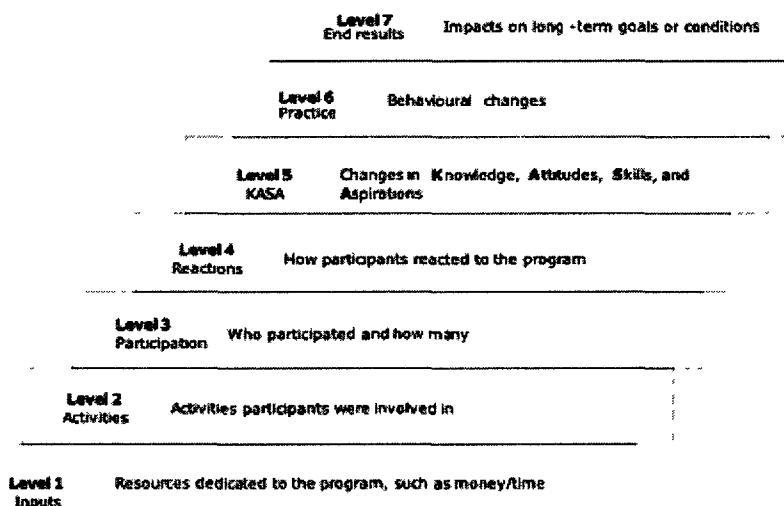


Figure 4.1 Bennett's Hierarchy of Evidence. Source: Bennett, 1976

It was not until asked to evaluate some NGO agricultural extension programs in Africa, during the 1990s (chapter 1.3) that personal observations of centrally directed informal science education efforts revealed those efforts to be far removed from the daily reality of the people they were supposed to serve. The programs were in disarray because of the presumptive educational attitudes common within ivory towers. Shortly thereafter, I left the Cooperative Extension System. The SENCER initiative had not yet been introduced, nor had formal university teaching experiences and associations with rural Native American communities begun for me either.

Dr. Ray Barnhardt (1986), who was already deeply involved in efforts to help University of Alaska Fairbanks faculty adapt to meet the needs of rural Alaskan Native communities, visited with Dr. Kathleen Ross, the founding President of Heritage College (founded in 1982, changed to Heritage University in 2004), located on the Yakama

Reservation in Washington State. He gave to her a copy of his (then) recent paper, *Domestication of the Ivory Tower* (Barnhardt, 1986), which was passed along to me, just a few years ago. In his paper, Barnhardt noted that field-based students and campus-bound students differed primarily in their ability to ground their university knowledge “to use their training in ways that are compatible with the ways of thinking and behaving preferred in their community” (Barnhardt, 1986, p. 6). Later, Native American writers, such as Kawagley (1995) and Cajete (2000), provided explanations why land, languages, customs and holistic beliefs of people have made it difficult to integrate Western science into local communities, especially if it is taught/learned in the absence of that environment. Interested readers should refer to those writings directly and to other field-based research studies, which are often termed “place-based” studies by education researchers.

In 2006, a personal project was begun with the Fred Hutchinson Cancer Research Center’s Science Education Partnership (SEP) Project, in which natural dyes were used to teach concepts in chemistry. The project was originally designed to provide a series of chemistry laboratory activities for one of my colleagues teaching chemistry at the Yakama Nation Tribal School (YNTS), a local high school where outreach science labs were frequently done (a sample laboratory lesson is included in Appendix C). In 2008, those high school laboratory activities were beginning to generate community interest among the families of YNTS students and particularly among traditional weavers. Since there were few studies on how much chemistry could be taught through high school outreach programs and informal workshops in Native American communities, more

documentation of the process and experiences, from the point-of-view of those participating, could provide some preliminary data for anyone contemplating increased science outreach. The NSF-SENCER assessment instrument, known as the Self-Assessment of Learning Gains (SALG), was selected to provide measures of learning outside of university science courses. Although arguably another secular Western methodology for outcomes assessment, a closer look at the SALG reveals that it is capable of being adapted to evaluate integrated, place-based, culturally situated knowledge. It may not evaluate that knowledge as thoroughly as other qualitative methods, but the combination of quantitative and qualitative data provided by the SALG make it an improvement upon typical outcomes assessments. SENCER staff had accumulated data for over 500 university courses, yet, to my knowledge, the instrument had never been tested outside of university classrooms. As high school science outreach and community dye workshops began to develop, I designed a study to compare community participant self-assessments with the self-assessments of students in university introductory chemistry courses. For additional comparisons, faculty at UAF agreed to include self-assessments of students in their introductory chemistry courses. The rationale for this work was based upon the ideas expressed by Barnhardt (1986):

In rural Alaska, where social issues are close to the surface, where institutional structures are still evolving, where cultural traditions are varied and rapidly changing, where economic problems are endemic and severe, and where new kinds of knowledge and skills are sorely needed, it is incumbent upon university faculty and the institution as a whole to become actively involved in the life of the

community, not just in the guise of “public service,” but as collaborators in the search for new understandings and new ways of doing things that will build upon, expand, and give recognition to all forms of knowledge. (p. 8)

### **4.3 The SENCER-SALG**

The SENCER Student Assessment of Learning Gains (SALG) originated from the research of Dr. Elaine Seymour (1998), who has been a SENCER consultant since the beginning of the SENCER initiative in 2000. Along with Dr. Tim Weston, an external evaluation of the SENCER project was published (Weston & Seymour, 2006), which was comprised of 345 university SENCER courses, with over 10,000 students, who completed the pre/post SALG survey. The findings included:

1. Students gained the most in science literacy and general course skills; projects and fieldwork were associated with confidence gains in science literacy and general science skills
2. Ten percent of the students changed from “no interest” to “extremely interested” in advanced science courses, between pre/post surveys
3. A 20% increase in civic engagement interest occurred, between pre/post surveys
4. Gains increased for women and non-science majors
5. Students in survey-based courses gained more than case-based courses
6. Faculty identified an array of institutional barriers to course implementation

A complete description of the SENCER SALG, along with copies of the evaluation, can be obtained from the SENCER website, [www.sencer.net](http://www.sencer.net), under the “Assessment”

heading (Weston & Seymour, 2006).

The SENCER-SALG is comprised of a series of questions, which allow students to identify and rate how much specific activities helped their learning. The pre/post questions compare student attitudes towards learning science at the beginning and end of courses. It is not meant to be used as a test or quiz. There are 10 basic question-stems; six about course design and practices and four about course learning objectives. Although the basic question-stems cannot be changed or deleted, sub-questions may be adapted to individual course objectives. The SALG website <http://salgsite.org> contains templates and analytical tools to assist instructors in customizing their instrument and in interpreting their assessment results.

Because the SENCER-SALG measures attitudes towards learning science, confidence about gains in science literacy, civic engagement interests, future interests in studying science; because it can associate gains in science literacy and general science skills with projects and field work; and because SENCER staff, already familiar with institutional barriers to course implementation, can assist faculty with new courses, it was believed that these instrument and organizational attributes could assist field-based faculty, who teach in Native American communities. Informal science education needs

“to extend beyond the usual generation and conveyance of literate knowledge, to include the institutional legitimation of indigenous knowledge and skills...not to train out of our students those very capacities, or the “Nativity” that we want them to bring into the school in the first place” (Barnhardt, 1986, p. 7).



#### 4.4 Summary

Since the NSF has expanded its primary mission of basic research, in the 1960s, to include science education, most of the initiatives have centered about university or K-12 science education, not wandering far from traditional formal instruction or supplemental after-school and short-term science exhibits. One exception is the SENCER initiative, which emphasizes civic engagement, collaboration among faculty, students and communities. The SENCER initiative includes an assessment instrument, known as the SALG, which allows participants to self-assess learning gains and attitudes towards science.

Native American writers and non-Native researchers, who have spent decades working and living within indigenous communities, have tried to convey the importance that land, language, community and customs all have upon integrating, or grounding, university knowledge (including Western science) into Native ways of life. The SENCER-SALG has been used with students, within university SENCER courses, but its potential uses, within alternative, place-based learning environments, has not been studied. Of particular interest was the SENCER data showing the SALG measured over a 20% increase in civic engagement interest and that non-science majors and women reported greater learning gains through the SENCER approach. Chapter 5 presents the results of an exploratory study, in which the SENCER-SALG was used to evaluate a series of informal workshops and compare those survey results with surveys of university students in chemistry courses for non-majors.

## Chapter 5

### Learning Gains and Attitude Reactions Study

#### 5.1 Introduction

This exploratory study is not intended to quantify participant's knowledge of chemistry, nor compare community knowledge of chemistry to that of university students. Rather, the purpose is to document and examine participants' self-assessments of their science learning gains and their attitudes towards chemistry within formal and informal learning environments. One goal is to examine participant responses for indications that the SENCER-SALG could substitute for quantitative assessments and inform field-based faculty of relative educational successes or failures, as they endeavor to adapt university science to local communities. This study focuses on level 4, *reactions*, of Bennett's model (Bennett, 1976). These *reactions* are critical to evaluation, yet commonly overlooked in education and extension programs.

#### 5.2 Objectives and Basis for Study

The objectives for using the SENCER-SALG, in science outreach and informal science education activities, were (a) to obtain, in the absence of direct assessment, correlative data through participant self-assessment of learning gains; (b) evaluate quantitative and qualitative data which could inform decisions to modify or change science outreach and education activities; (c) demonstrate the instrument's versatility and effectiveness outside of formal university science courses and classrooms.

Falchikov and Boud (1989) conducted a meta-analysis study, which compared faculty and student ratings of student performance to direct assessments of student

performance. They found that students rated themselves higher than faculty rated them, in absolute terms, but that the average correlation ( $r=.39$ ) was significant. Similarly, SALG researchers (Weston & Seymour, 2006) achieved an average correlation between direct assessments and student self-assessments of  $r=.41$ . While the correlations were moderate, both studies correlated higher self-assessments to higher levels of achievement, as measured by direct assessments. The SENCER-SALG was not intended to substitute for direct assessments used in formal classrooms, but in the absence of direct assessments, the correlation research suggested that SALG responses would provide evidence of learning within informal settings. This exploratory study examined the SENCER-SALG in learning environments where no direct assessment was used at all, a common occurrence outside of university classrooms.

Of the 1000 instructors, who used the original SALG instrument, in 3000 university courses, with over 65,000 participating students, 139 instructors were surveyed about their choice of the SALG instrument. Seventy-nine percent indicated they used the SALG primarily for course redesign:

The most frequently made change (60%) to course design were modifications to class activities (lecture, discussion, hands-on activities) followed by student learning activities (54%), course content (43%), and the information given to students (33%). Eighty-five percent reported that the SALG *provided qualitatively different and more useful student feedback* than traditional student course evaluations. (SALG, n.d.)

The data provided by the SENCER-SALG met the criteria for *evidence*, which cooperative extension agents have used for decades, as outlined in Boyle (1981):

Evidence is an indication, or an outward sign. In evaluation, evidence is composed of:

- 1 Acts, words, numbers, or things that provide a sign or indication
- 2 That which provides proof of the extent to which the quality we are examining is present in a program
- 3 That which, when accumulated into a pattern, provides a picture adequate for judging the extent to which criteria have been met...

Evidence can be what people say. . . . It can be what actually occurs or what people think occurs. . . . Records of behavior are the usually accepted evidence about the accomplishments of a program. . . . Ratings on attitude scales when the program deals with the affective domain. (pp. 226-7)

The SENCER-SALG was examined, within informal science education settings, to see if it informed faculty, who could then modify science education activities and content, “as collaborators in the search for new understandings and new ways of doing things that will build upon, expand, and give recognition to all forms of knowledge” (Barnhardt, 1986, p. 8).

### **5.3 Human Subjects Review Exemption**

The use of the SENCER-SALG data in this thesis meets exemption from full Human Research Committee Review as specified in 2005 Code of Federal Regulations (CFR)

Title 45, Part 46.101.b.1 (i) and (ii) and Part 46.101b.2 (i), for both Heritage University and the University of Alaska Fairbanks. Those exemptions are

- (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (2) Research involving the use of educational tests, (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects (U.S. Department of Health and Human Services, 2009).

Copies of the exemption notifications are in Appendix A.

#### **5.4 Quantitative Data Results**

With the exception of one community workshop, where computers were not available, participants entered survey responses online and the results were retrieved from the SALG website (SALG, n.d.). The website automatically calculated means, standard deviations, modes and generated graphs of the data, which provided an easy-to-read overview, with data variance depicted as error bars about the means. Individual responses could be singled out from group data, if desired; for instance, if a respondent marked the same response to every question, that data could be singled out. Surveys could be analyzed alone or combined with other surveys into a composite sample. Both types of

analysis were used in this report. The groups with both pre-course/workshop and post-course/workshop surveys were

1. UAF CHEM 100 students (Spring and Fall 2009 semesters), who participated in the SENCER-SALG surveys but who had no contact with the author. The students did not discuss traditional Native American knowledge, related to dyes and pigments, in that course.
2. HU CHEM 101 students (Spring 2009 semester), who completed laboratory sessions using natural dyes, but who received no instruction, relating natural dyes to traditional Native American knowledge, nor did they participate in any class discussions about Native American cultures.
3. A 3-hour workshop for advanced placement high school Biology and chemistry students, in which natural dyes were used to teach concepts related to pH. At the workshop, a Yakama elder described why dyes were important to Native Americans and also taught students Sahaptin names for the colors.
4. Two separate 6-hour dye workshops for Native American weavers; one also included several non-Native weavers and artists. Elders in attendance participated in pH experiments, and then they used dyed materials to demonstrate their weaving skills, told stories to others present, and assisted people with their weaving.

The two UAF CHEM 100 course surveys (two combined semesters of pre- and post-course responses) served as a control group, representing before/after attitudes and self-assessments from students who had no interaction with this study, other than

completing the modified SENCER-SALG surveys. CHEM 100 was a course for non-science majors and utilized the American Chemical Society's text "Chemistry in Context," an issues-based text which had previously been combined with traditional knowledge, to engage students in science (Duffy, Middlecamp, Godduhn, & Fabbri, 2009). The UAF instructor had prior experience using the SENCER-SALG. Thirty (30) of the students enrolled in either the Spring or Fall 2009 UAF CHEM 100 courses voluntarily completed the pre-course surveys. See Appendix B for an example of the SENCER-SALG survey.

This analysis focused on student self-assessment of "understanding," one of the ten question-stems in the SENCER-SALG and the first question-stem of the pre-course survey. Students were asked questions about their understanding of dyes and pigments, pH, the Periodic Table of Elements, balancing equations - 15 questions in all. The Lichert scale response options to the statement, "Presently, I understand..." were 1: Not applicable, 2: Not at all, 3: Just a little, 4: Somewhat, 5: A lot, 6: A great deal. (Note: the phrases in quotations are shortened versions of actual survey questions)

In the UAF CHEM 100 course, the lowest student responses were about dyes and pigments. They ranged from a mean of  $1.8 \pm .46$  for "scientific names for dyes, pigments" (not at all; Figure 5.1) to a mean of  $2.5 \pm 1.04$  for "the importance of dyes and pigments to my culture" (not at all to just a little, Figure 5.2) with 20% of the respondents indicating that dyes and pigments were not applicable to the course. Questions about their understanding of "The Periodic Table of the Elements" resulted in a mean of  $3.9 \pm 1.22$  (Figure 5.3) and "the chemistry term pH" with a mean of  $3.8 \pm 1.03$  (Figure 5.4). Those

were the highest understanding levels recorded, even though one student stated that pH was not applicable to the course.

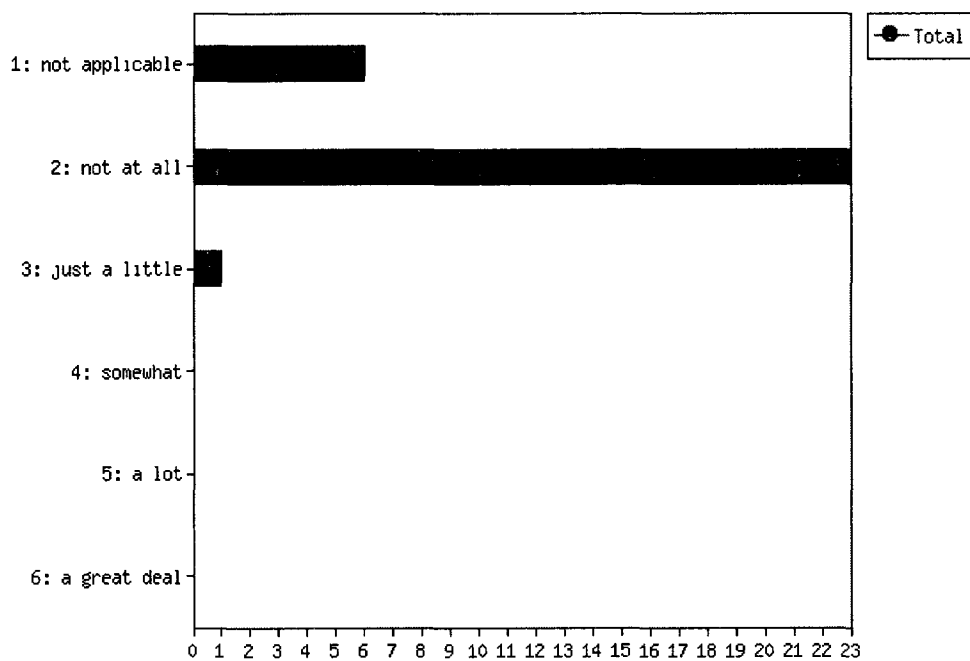


Figure 5.1 UAF Pre-course Responses to “Scientific names for dyes and pigments”



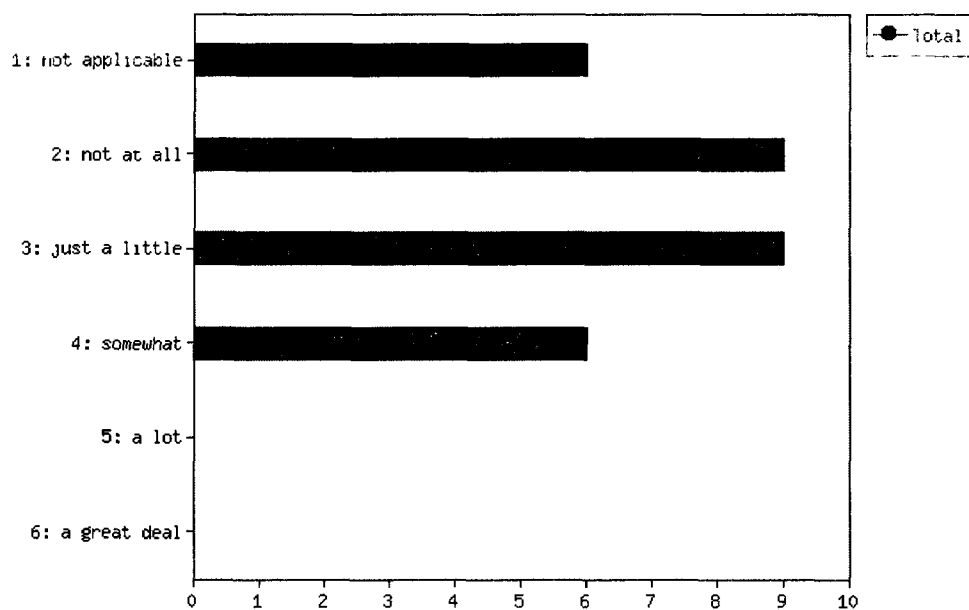


Figure 5.2 UAF Pre-course Responses to “Importance of dyes and pigments to culture”

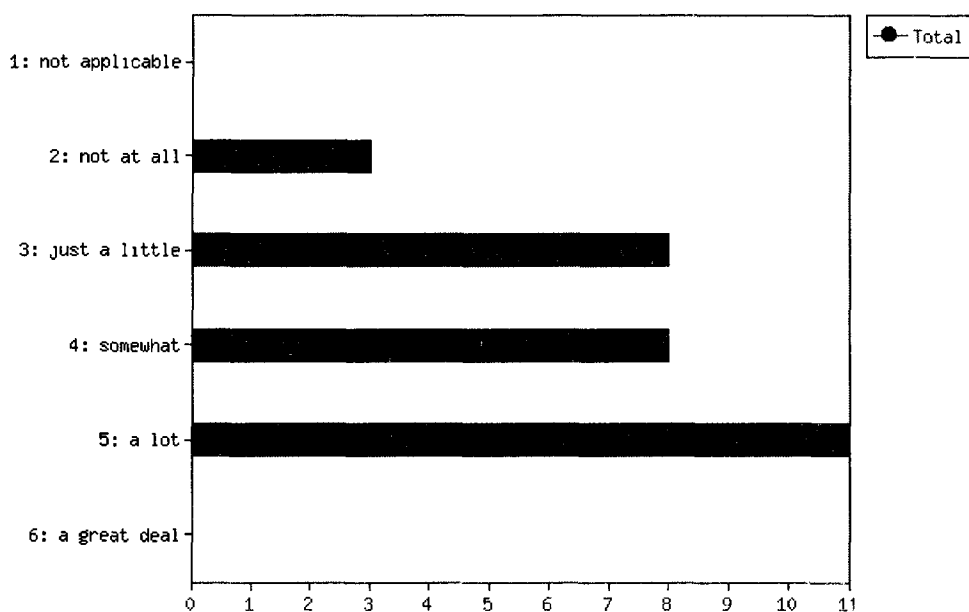


Figure 5.3 UAF Pre-course Responses to “The Periodic Table of Elements”

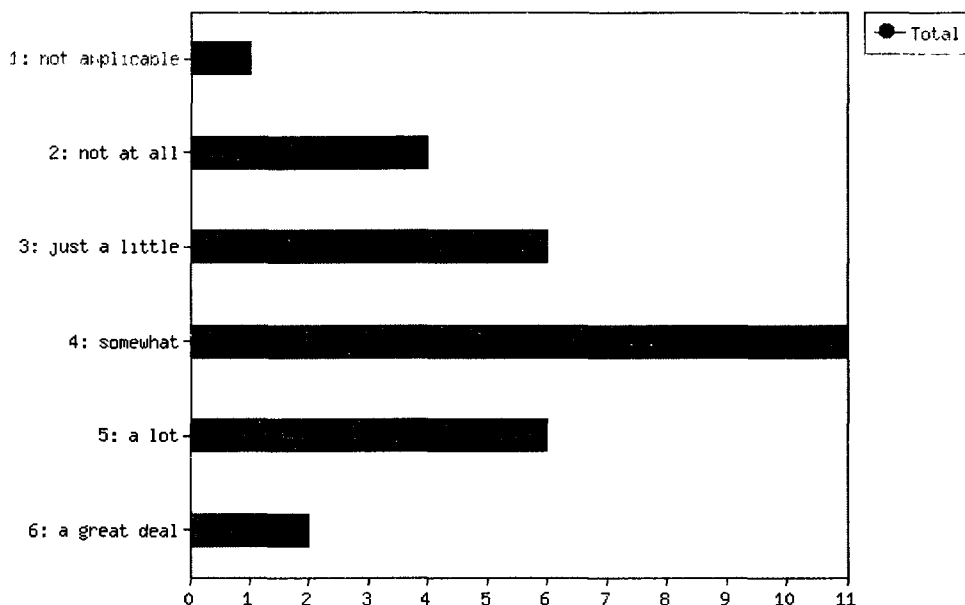


Figure 5.4 UAF Pre-course Responses to “The chemistry term pH”

In the post-course survey, 28 UAF students voluntarily completed responses. Responses to the question “As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of each of the following?” had the following Lichert scale options: 1: no gains, 2: a little gain, 3: moderate gain, 4: good gain, 5: great gain, 9: not applicable (score not tallied in mean). The numerical means of the pre-course and post-course surveys were not equivalent; the pre-course survey measured a current self-assessment of understanding, while the post-course survey allowed participants to reassess their understanding, in terms of how much they thought they gained. The greatest gain reported was “the chemistry term pH,” with a mean of  $4.4 \pm .96$  (good to great gain, Figure 5.5), followed by “how this course relates people to world issues,”  $4.3 \pm 1.01$  (good gain, Figure 5.6) and “the Periodic Table of the Elements,”  $4.2 \pm .96$  (good gain,

Figure 5.7). The lowest gains reported were for “the chemistry term mordant,” with a mean of  $2.4 \pm 1.3$  (a little gain, Figure 5.8) followed by “local or ethnic names for dyes and pigments,  $2.6 \pm 1.36$  (little to moderate gain, Figure 5.9). Over one third (35%) of the students selected “not applicable” to the dye-related questions. Those responses were excluded from mean calculations.

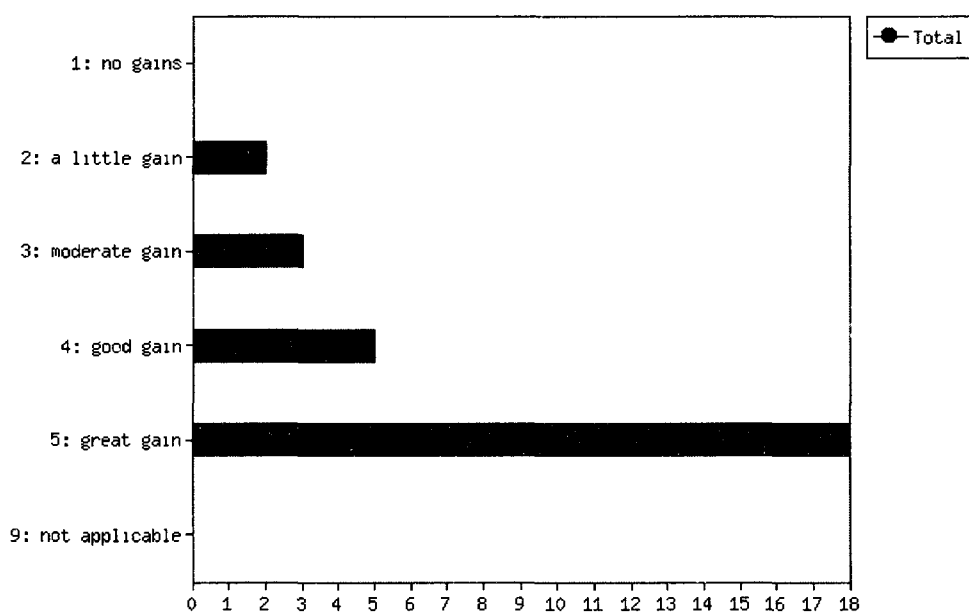


Figure 5.5 UAF Post-course Responses to “The chemistry term pH”

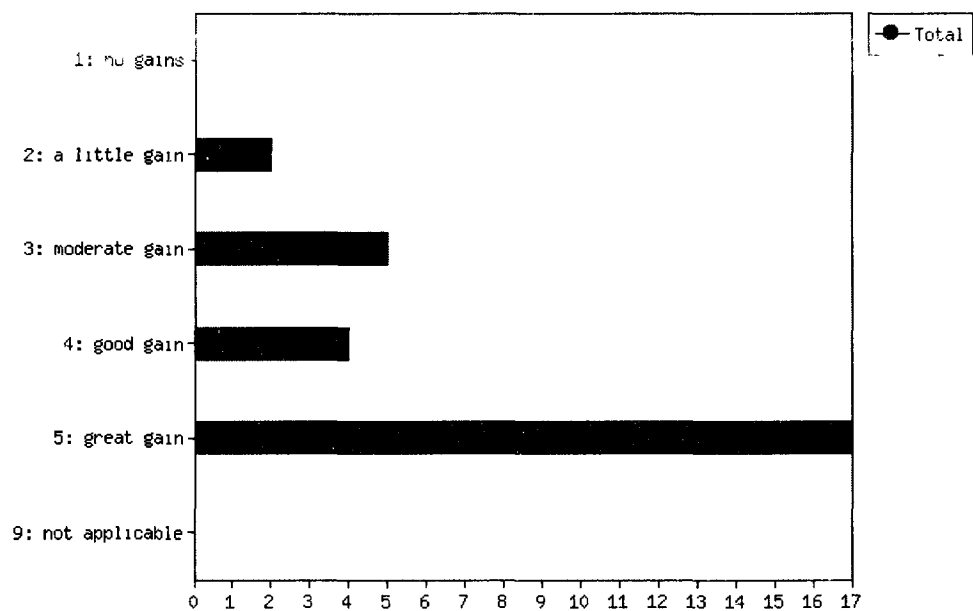


Figure 5.6 UAF Post-course Responses to “How course relates people to world issues”

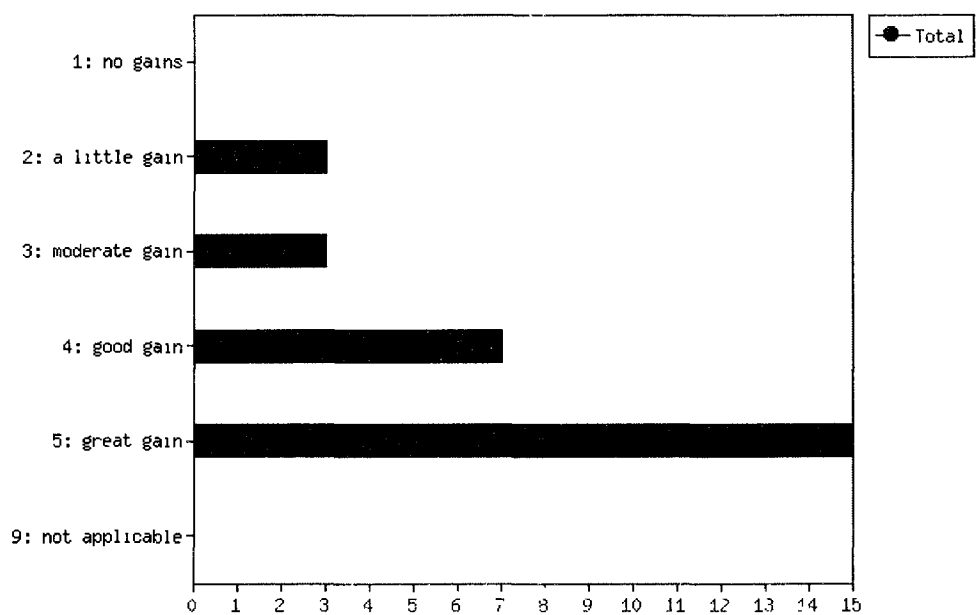


Figure 5.7 UAF Post-course Responses to “The Periodic Table of Elements”

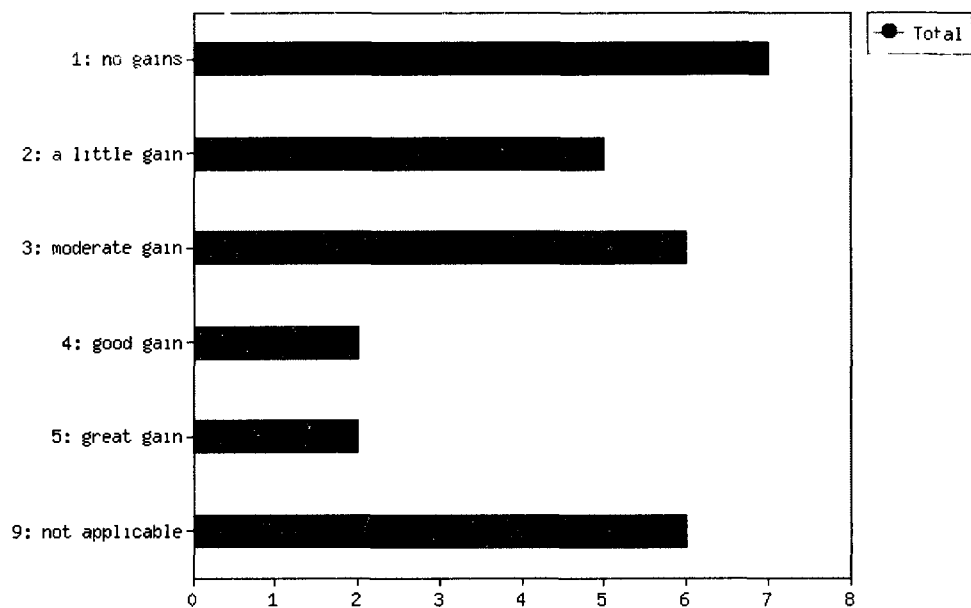


Figure 5.8 UAF Post-course Responses to “The chemistry term mordant”

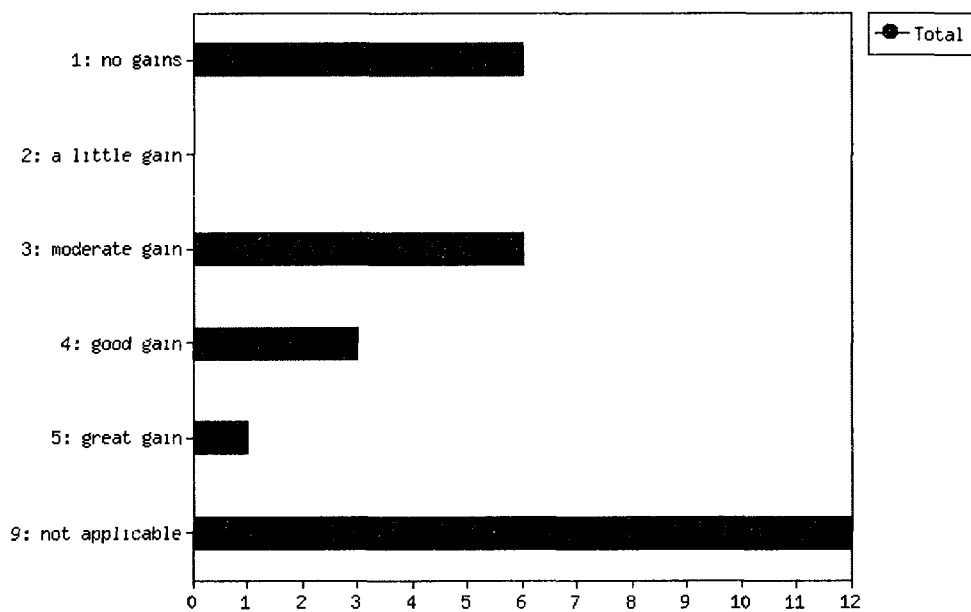


Figure 5.9 UAF Post-course Responses to “Local or ethnic names for dyes/pigments”

The HU CHEM 101 course was also for non-science majors and the content was very similar to the UAF CHEM 100 course. Unlike the UAF course, Timberlake's (2006) text was not an issues-based text. The course also differed from the UAF course because natural dye laboratory experiments were substituted for standard pH and solution chemistry lab experiments. The pre-course and post-course surveys were identical to those completed by UAF CHEM 100 students. Twenty six (26) students completed the pre-course survey and 20 completed the post-course survey. In the HU CHEM 101 pre-course survey, the two lowest student responses to "Presently I understand..." were "the chemistry term mordant" with a mean of  $2.2 \pm .71$  (not at all, Figure 5.10) and "scientific names for dyes, pigments" with a mean of  $2.2 \pm .59$  (not at all, Figure 5.11), with just under 10% of students marking "not applicable." The highest responses were for "The Periodic Table of Elements" with a mean of  $3.8 \pm .75$  (just a little to somewhat, Figure 5.12) and "the chemistry term pH" with a mean of  $3.6 \pm 1.42$  (just a little to somewhat, Figure 5.13).

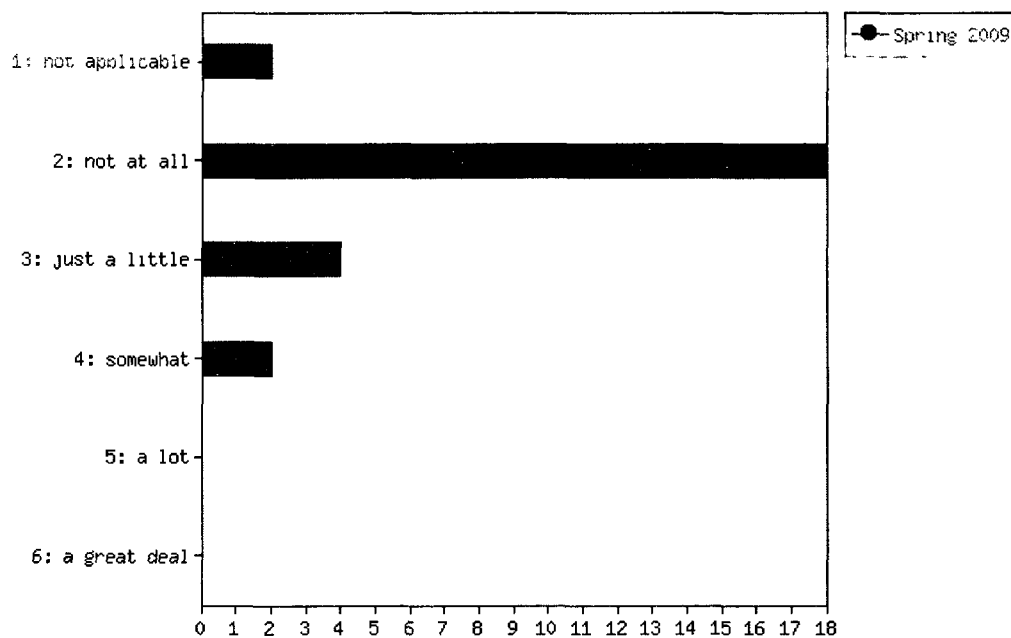


Figure 5.10 HU Pre-course Responses to "The chemistry term mordant"

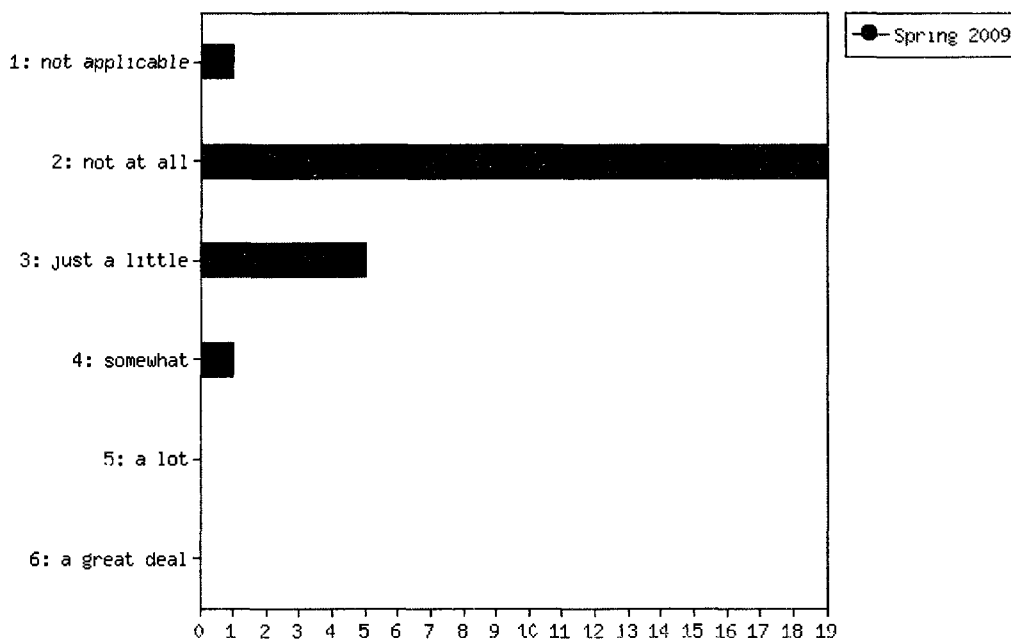


Figure 5.11 HU Pre-course Responses to "Scientific names for dyes/pigments"

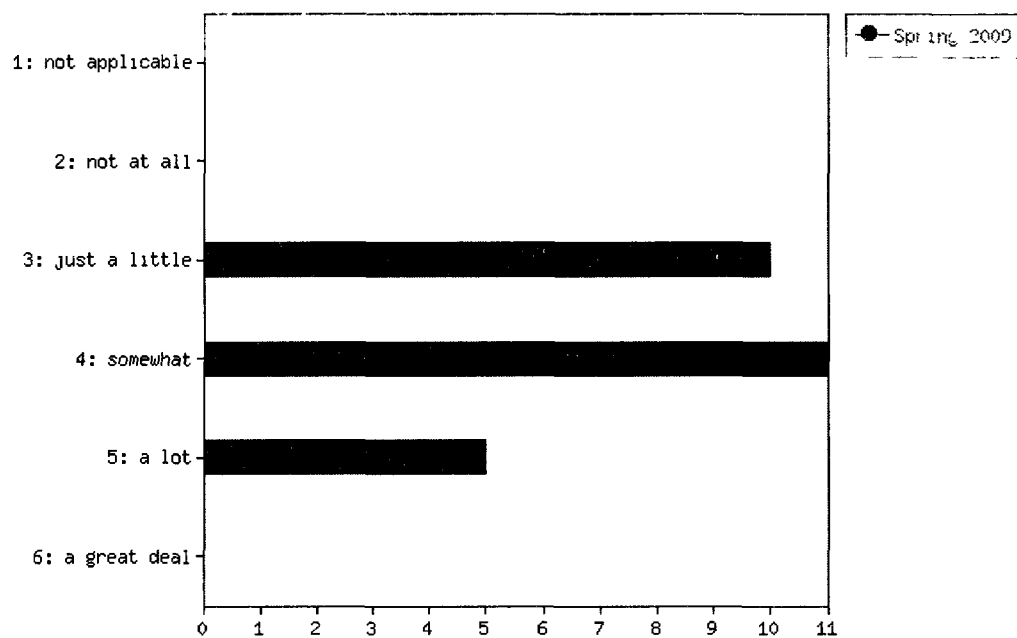


Figure 5.12 HU Pre-course Responses to "Periodic Table of Elements"

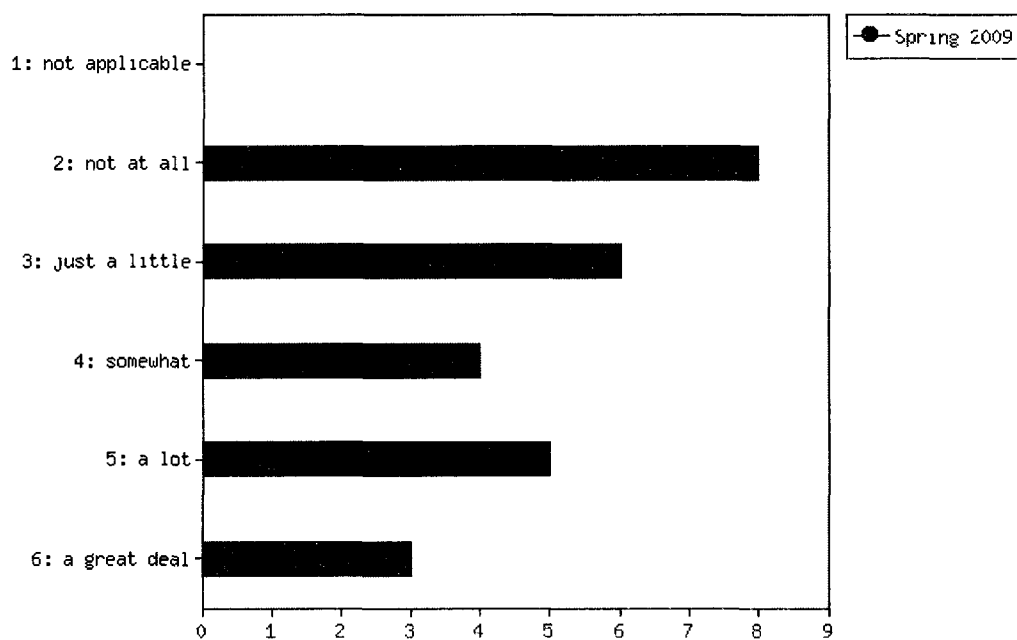


Figure 5.13 HU Pre-course Responses to "The chemistry term pH"



In the HU CHEM 101 post-course survey, the two highest responses to the question “As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of each of the following?” were “the chemistry term pH” with a mean of  $4.5 \pm .69$  (good to great gain, Figure 5.14) and “The Periodic Table of the Elements” also with a mean of  $4.5 \pm .69$  (good to great gain, Figure 5.15). The lowest responses included “Local or ethnic names for dyes and pigments” with a mean of  $3.3 \pm .82$  (moderate gain, Figure 5.16) and “scientific names for dyes and pigments” with a mean of  $3.5 \pm .90$  (moderate gain, Figure 5.17). No student selected “not applicable” for any question.

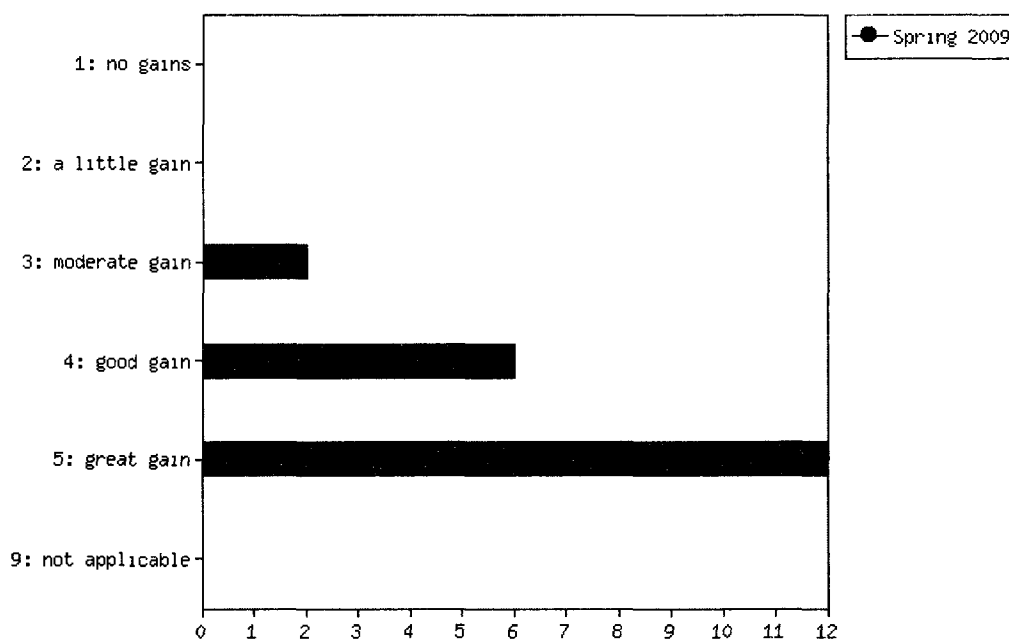


Figure 5.14 HU Post-course Responses to “The chemistry term pH”

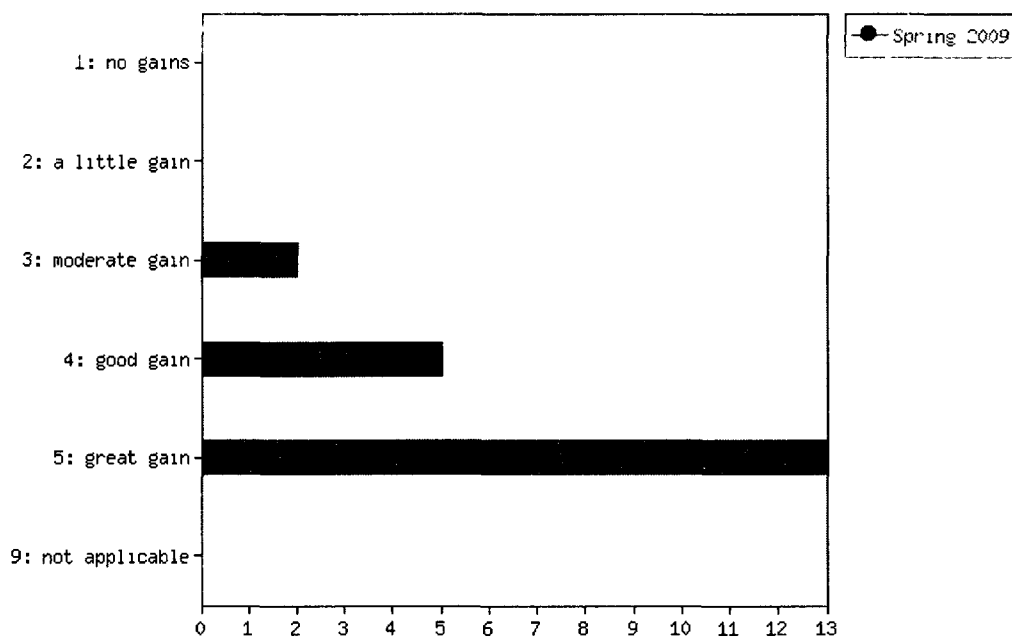


Figure 5.15 HU Post-course Responses to “The Periodic Table of Elements”

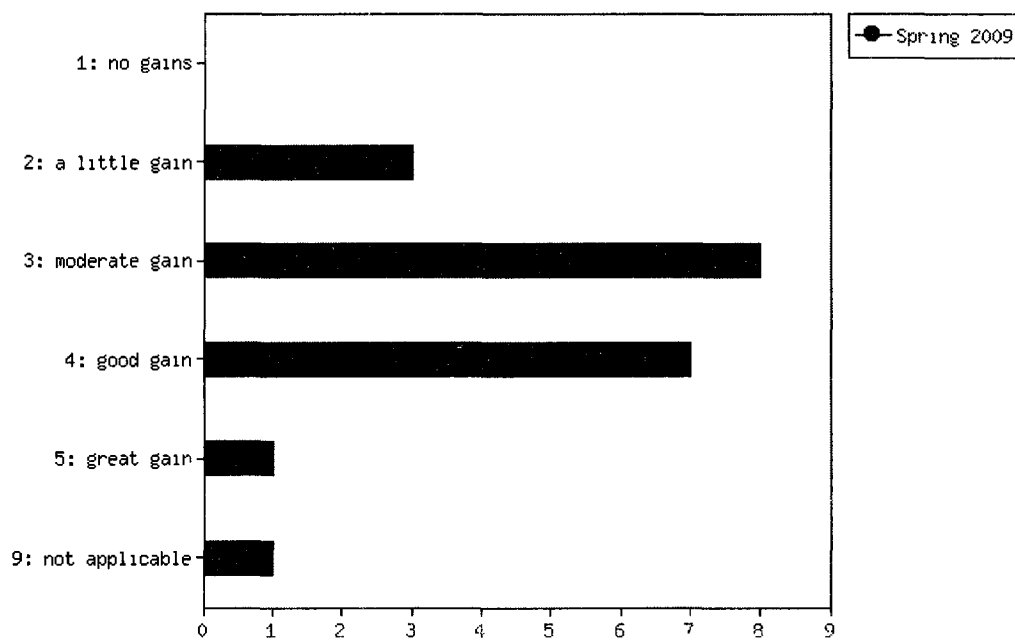


Figure 5.16 HU Post-course Responses to “Local or ethnic names for dyes/pigments”

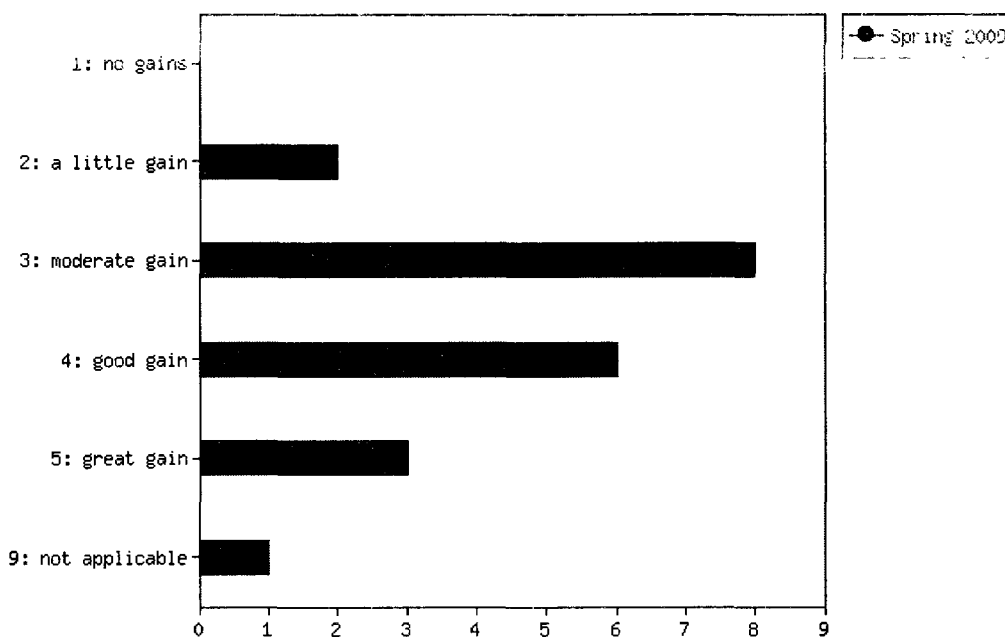


Figure 5.17 HU Post-course Responses to “Scientific names for dyes/pigments”

For the high school workshop, in which 12 advancement placement biology and chemistry students participated, the pre-course survey of present understanding resulted in the lowest responses for “the chemistry term mordant” with a mean of  $1.9 \pm .29$  (not at all, Figure 5.18) and “scientific names for dyes and pigments” with a mean of  $2.1 \pm .29$  (not at all, Figure 5.19), while the highest responses were for “The Periodic Table of Elements” with a mean of  $4.8 \pm 1.42$  (a lot, Figure 5.20) and “Names of chemicals” with a mean of  $4.4 \pm 1.51$  (somewhat to a lot, Figure 5.21). Responses to “the chemistry term pH” followed several other questions, with a mean of  $3.3 \pm 1.15$  (just a little, Figure 5.22).

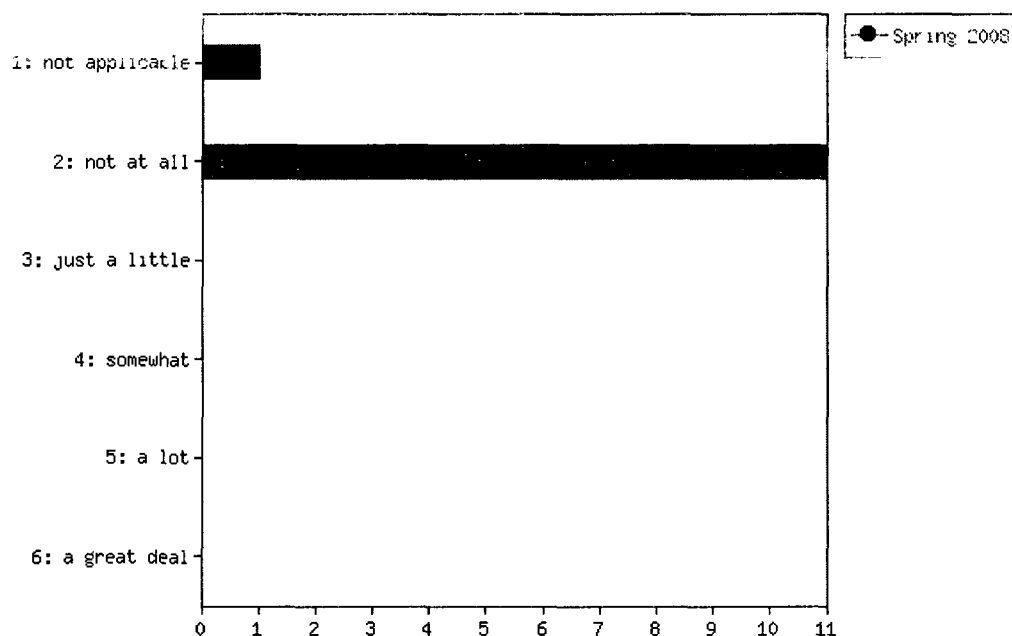


Figure 5.18 HS Pre-course Responses to "The chemistry term mordant"

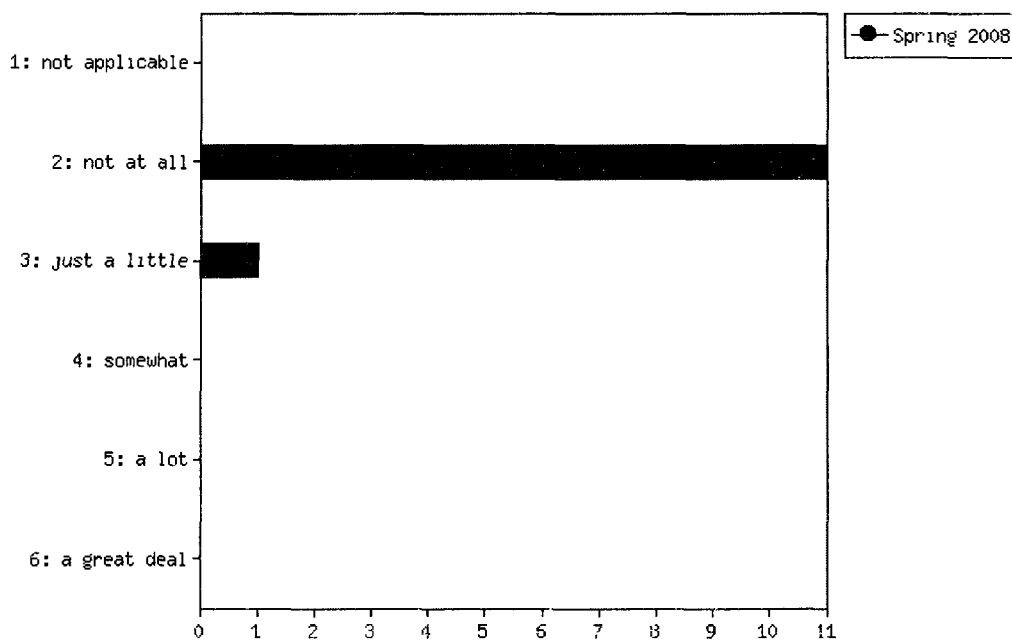


Figure 5.19 HS Pre-course Responses to "Scientific names for dyes/pigments"

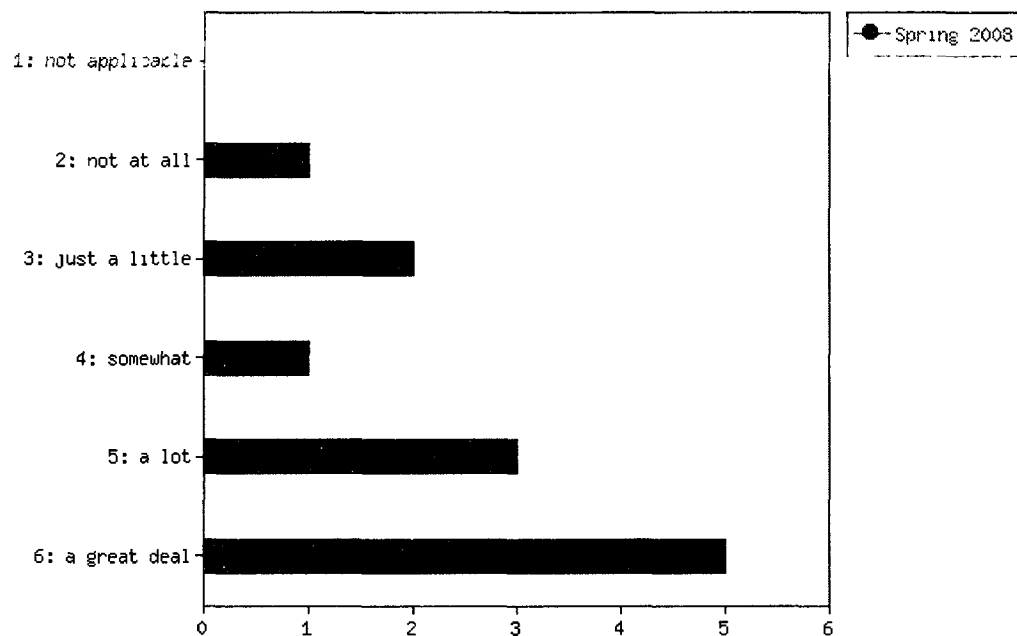


Figure 5.20 HS Pre-course Responses to “The Periodic Table of Elements”

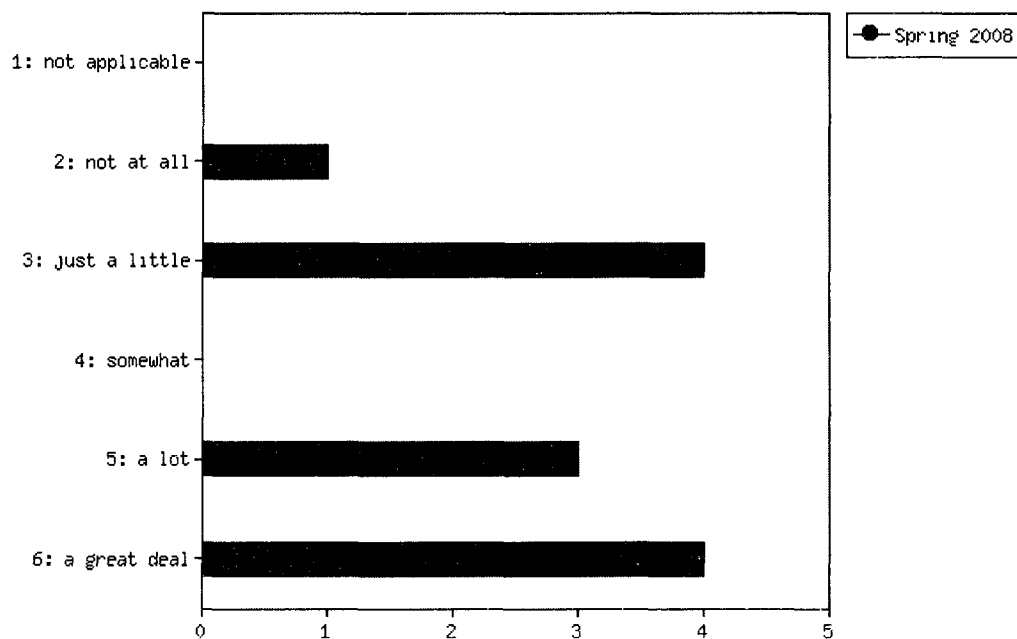


Figure 5.21 HS Pre-course Responses to “Names of chemicals and compounds”

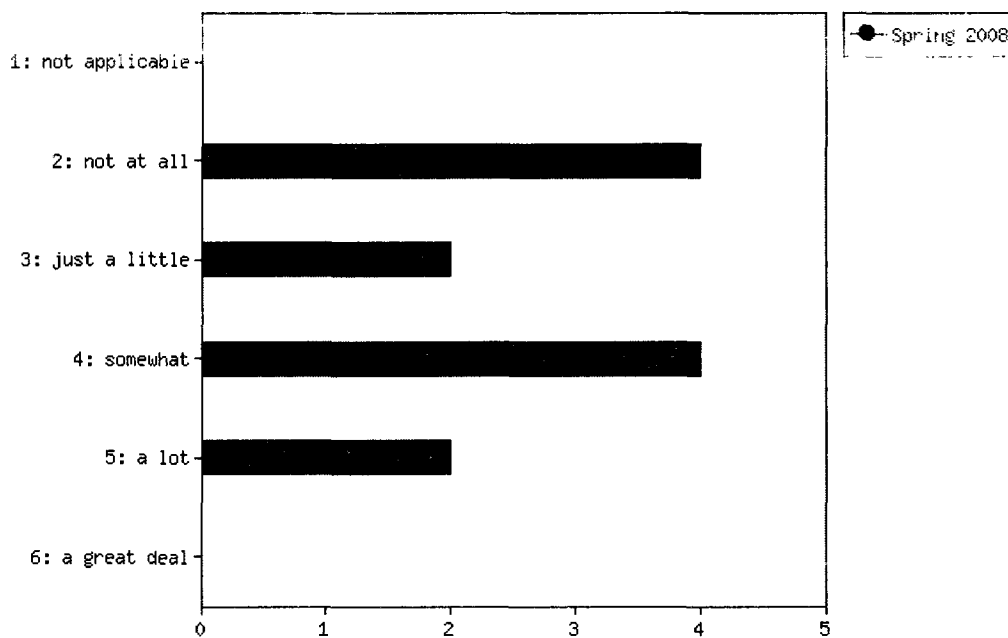


Figure 5.22 HS Pre-course Responses to “The chemistry term pH”

After the 3-hour workshop, the same students responded that their greatest gains in understanding were “the chemistry term pH” with a mean of  $4.4 \pm 1.0$  (8 of 12 students reported “great gain,” Figure 5.23) and “preparing materials for dyes and pigments” with a mean of  $4.2 \pm .75$  (good gain, Figure 5.24). Responses with the least gains reported were “how ideas in this class relate to other cultures” with a mean of  $2.9 \pm 1.60$  (2 students responded “not applicable,” Figure 5.25) and “how this course relates people to world issues” with a mean of  $3.0 \pm 2.0$  (5 of the 12 students responded “not applicable” while the remaining students reported moderate gains, Figure 5.26).

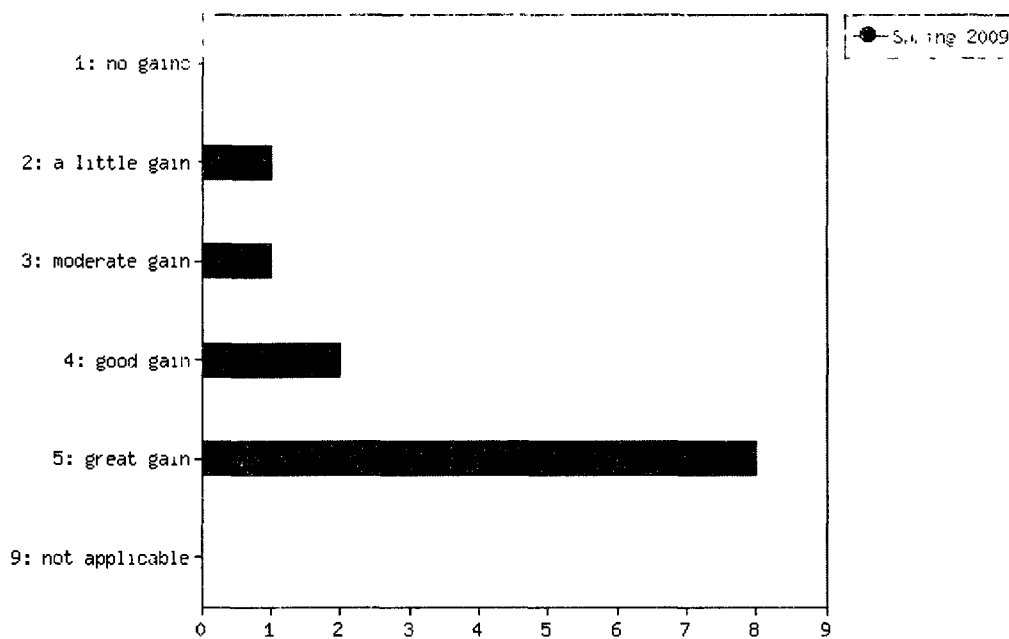


Figure 5.23 HS Post-course Responses to “The chemistry term pH”

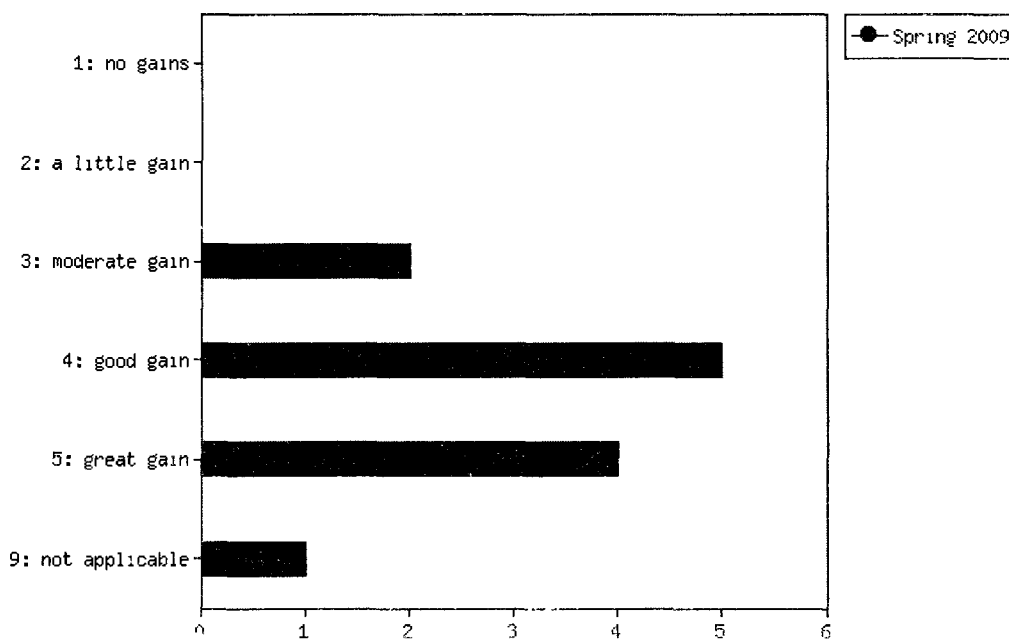


Figure 5.24 HS Post-course Responses to “Preparing materials for dyes/pigments”

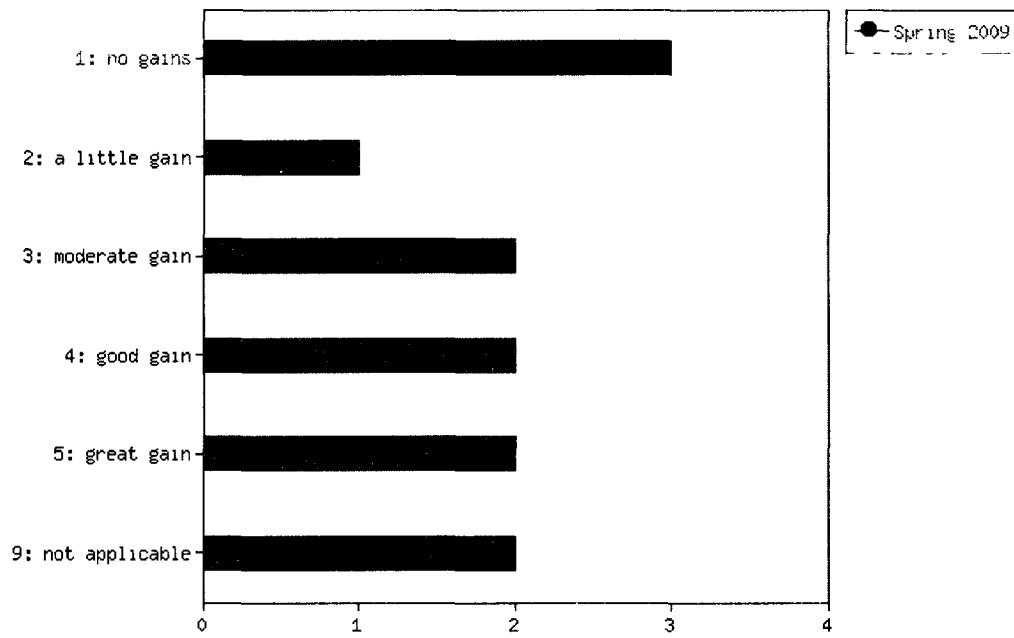


Figure 5.25 HS Post-course Responses to "How ideas relate to other cultures"

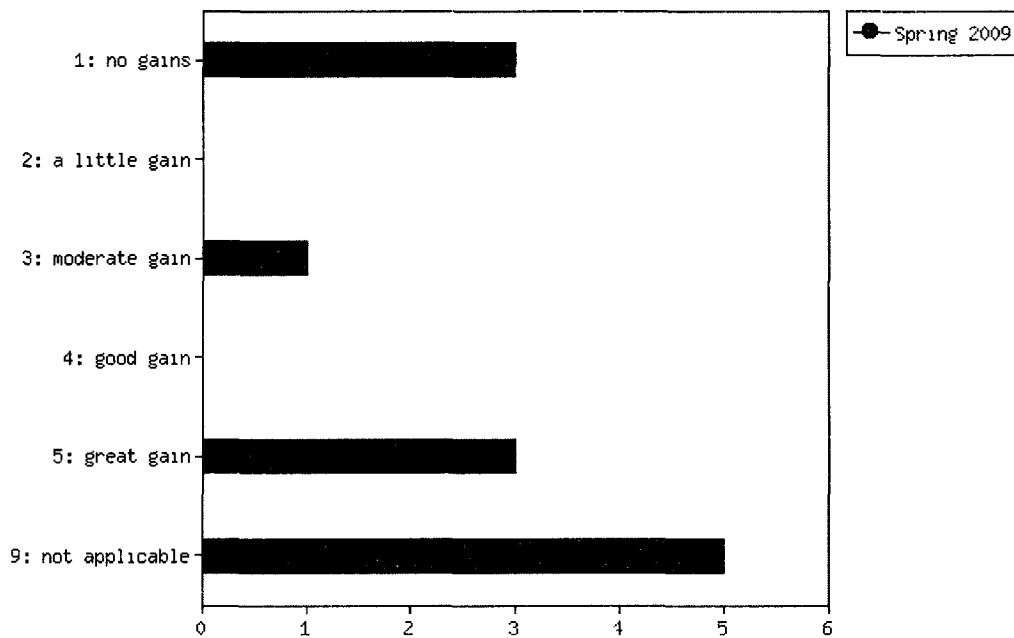


Figure 5.26 HS Post-course Responses to "How this relates people to world issues"



A two-day, 6-hour workshop was held for weavers at the Tamastlikt Cultural Center, in Pendleton, Oregon. Over 20 weavers and artists attended, from three states, with several Native American elders among them. Two elders drove 200 miles to attend a second workshop at HU, arranged especially for them. With only four participants at the second workshop, both data sets were combined for analysis in this study.

In the pre-workshop surveys, the two lowest responses for understanding were “Native names for dyes, pigments and processes in using them” with a mean of  $2.3 \pm .69$  (not at all, Figure 5.27) and “how pH and mordants change colors” with a mean of  $2.4 \pm .70$  (not at all to just a little, Figure 5.28) while the highest responses were “the importance of dyes and pigments to my culture” with a mean of  $3.7 \pm 1.5$  (8 responded “not at all” and 8 responded either “a lot” or “a great deal,” Figure 5.29) and “the chemistry term pH” with a mean of  $3.1 \pm 1.03$  (just a little, Figure 5.30).

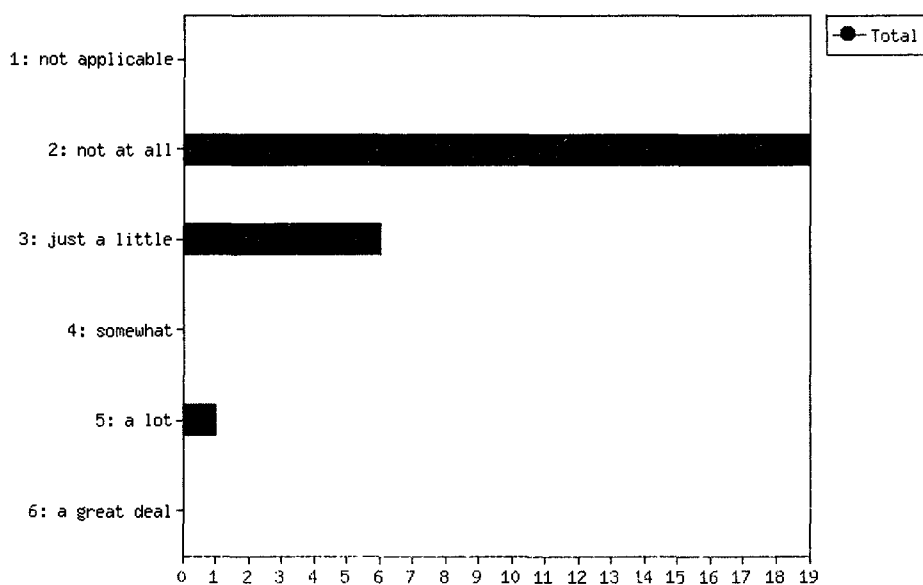


Figure 5.27 Tamastlikt Pre-course Responses to “Native names for dyes/pigments”

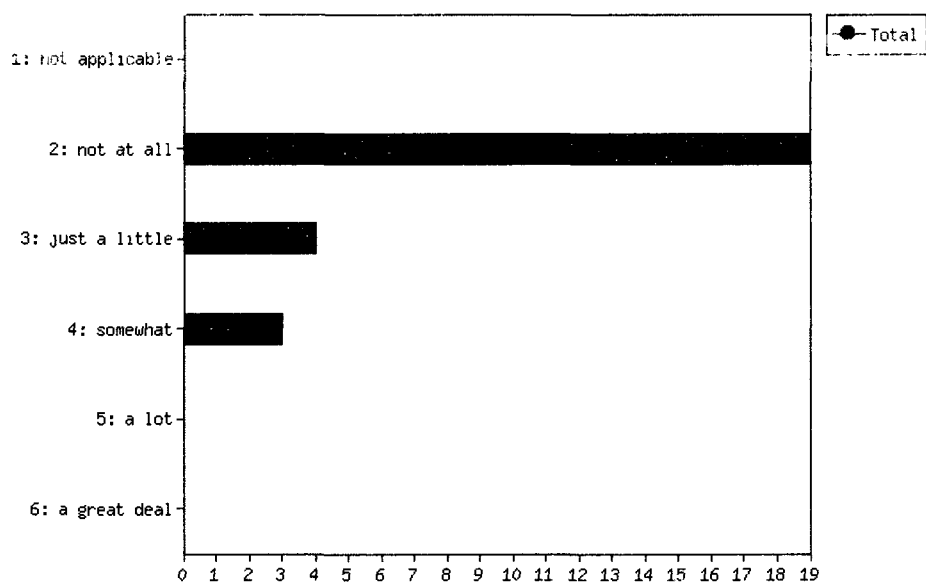


Figure 5.28 Tamastlikt Pre-course Responses to "How pH/mordants change colors"

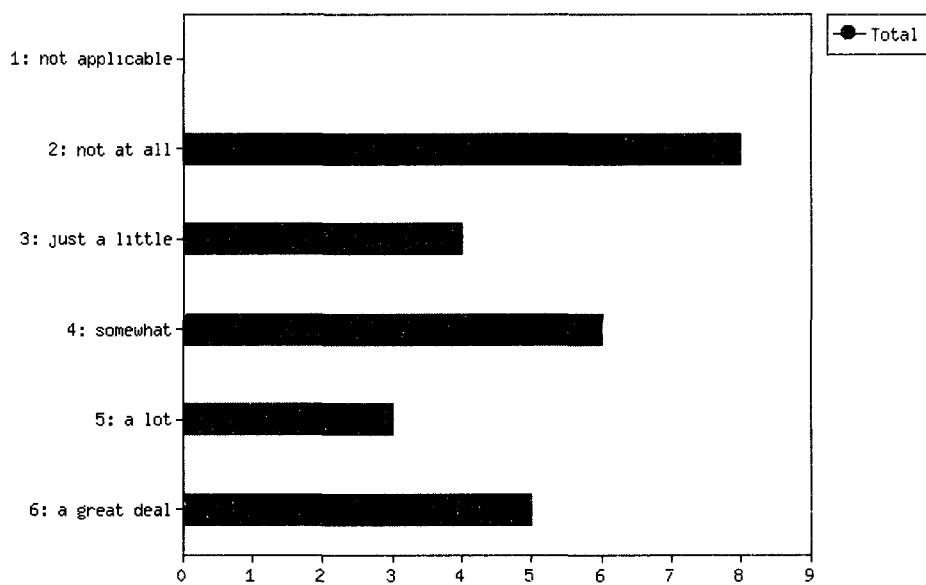


Figure 5.29 Tamastlikt Pre-course Responses to "Importance of dyes/pigments"

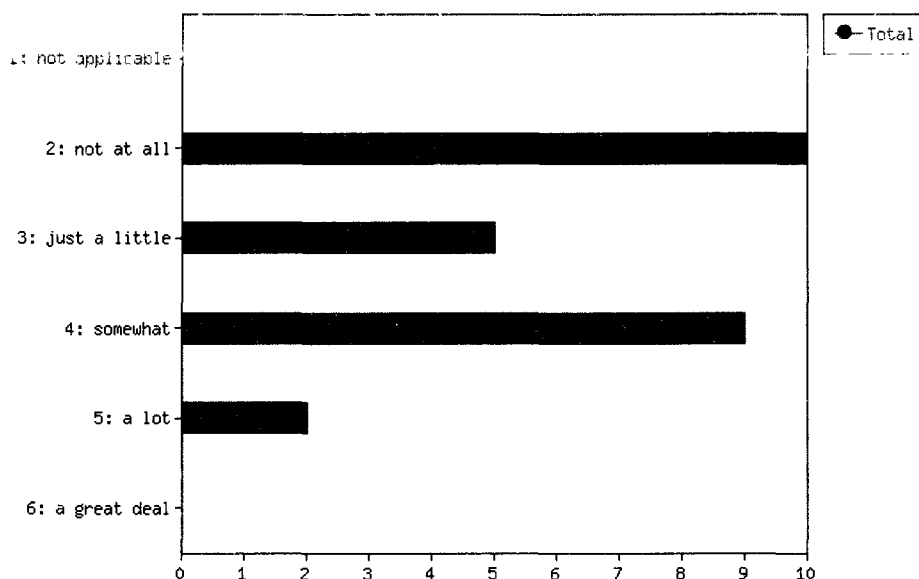


Figure 5.30 Tamastlikt Pre-course Responses to “The chemistry term pH”

The post-workshop survey, which indicated participant assessments of their gains, had several high responses with means of 4.2 and standard deviations between 0.5 and 1.0: “differences between dyes and pigments” (Figure 5.31), “how to obtain and extract natural dyes and pigments” (Figure 5.32), and “the importance of dyes and pigments to my culture” (Figure 5.33). All reported good gains in understanding. The lowest responses were “balancing equations” with a mean of  $2.2 \pm 1.14$  (a little gain, with over 60% of participants reporting no gain or not applicable, Figure 5.34) and “names of elements and compounds” with a mean of  $2.4 \pm 1.19$  (a little gain, with 50% of participants reporting no gain or not applicable, Figure 5.35).

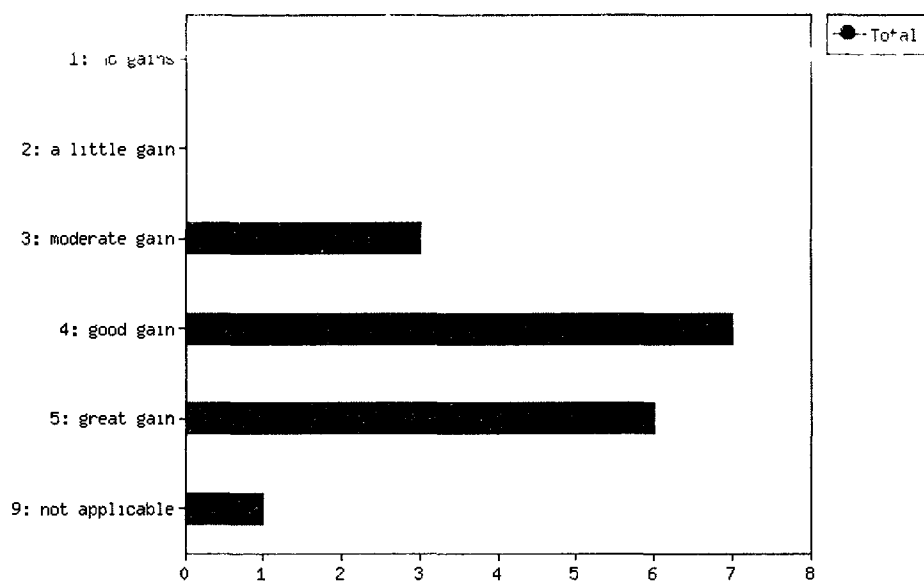


Figure 5.31 Tamastlikt Post-course Responses to “Differences between dyes/pigments”

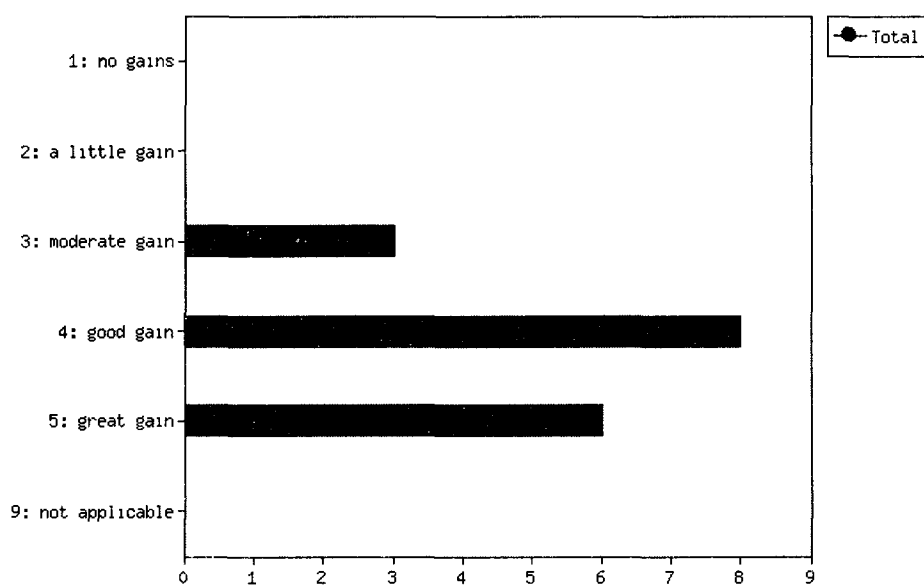


Figure 5.32 Tamastlikt Post-course Responses to “How to obtain/extract dyes/pigments”

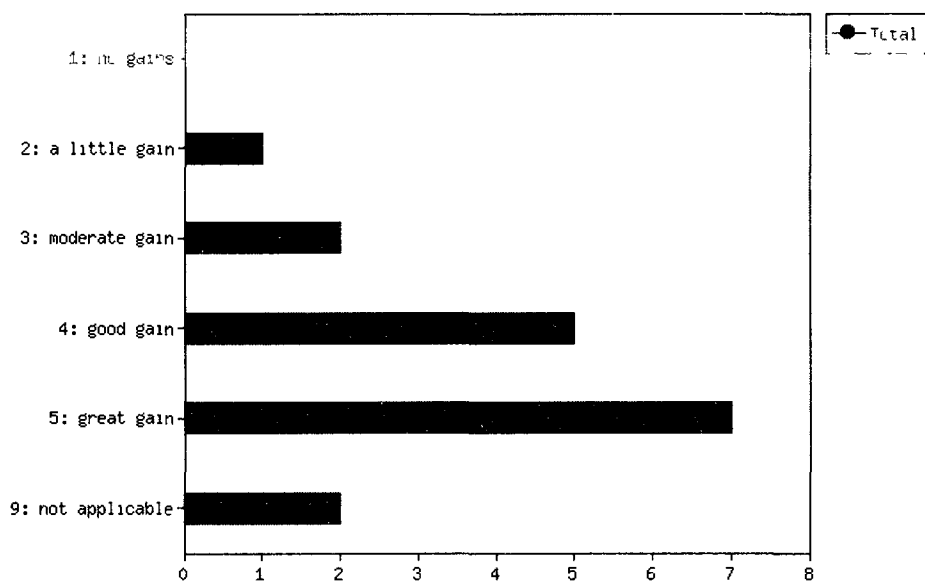


Figure 5.33 Tamastlikt Post-course Responses to “Importance of dyes/pigments”

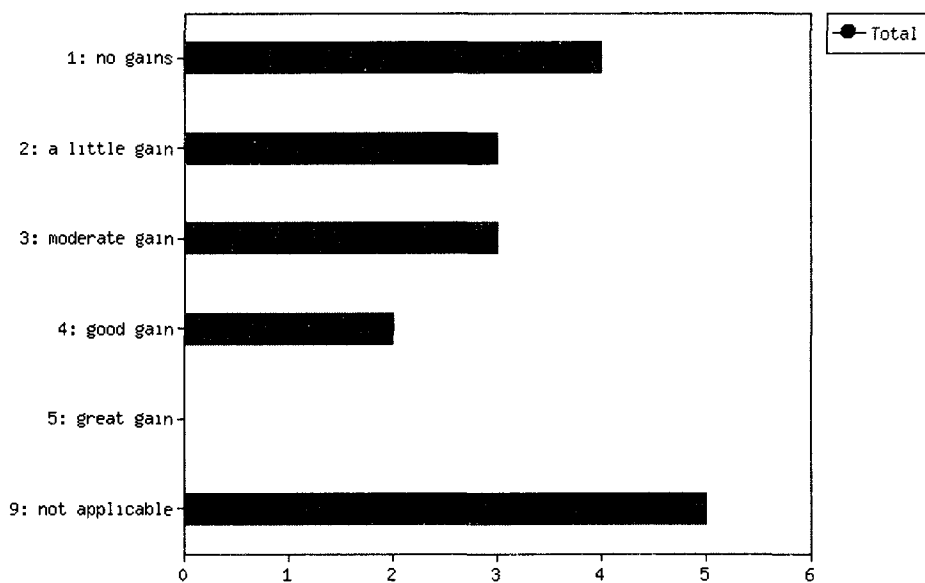


Figure 5.34 Tamastlikt Post-course Responses to “Balancing equations”

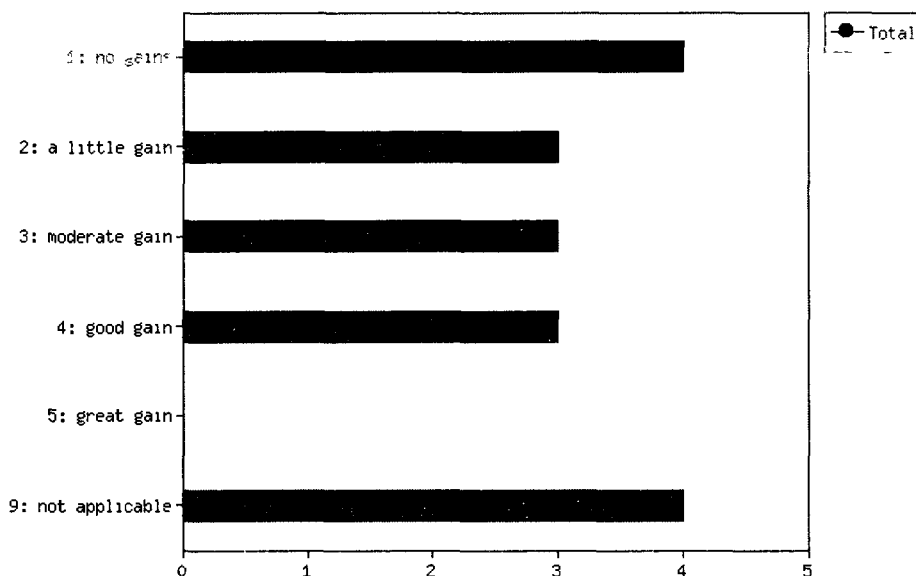


Figure 5.35 Tamastlikt Post-course Responses to “Names of elements”

### 5.5 Discussion of Quantitative Data: University Courses

In both the UAF and HU chemistry courses for non-majors, students claimed, in the pre-course survey, that “The Periodic Table of Elements” and “the chemistry term pH” represented their highest level of current understanding in chemistry, although their responses were between “just a little” and “somewhat” levels. Notably, both UAF and HU students also claimed that their greatest gains in understanding occurred in those same two areas, with responses consistently in the “good” to “great gain” categories.

This is consistent with and similar to the findings of some researchers in other fields of study. A colleague in the Department of Social Work (Dr. Ray Bending, personal communication, February 18, 2010) stated that for many years, he used a “Can Do” survey with students beginning in his program. While they did not score learning gains as in the SENCER-SALG, when students were asked to evaluate their knowledge

before a course and then re-evaluate it at the end of a course, their scores dropped. Most students, who rated their knowledge and skills “high” at the beginning of the course, rated that same knowledge and skills lower at the end of the course. Once they realized how much there was to learn and what the knowledge and skills really entailed, students were able to more realistically assess themselves. Subsequently, when graduates of Dr. Bending’s program entered master’s programs at other universities, several contacted him and remarked that they were finally beginning to understand what he had been trying to teach them.

Another observation was made in a reading comprehension study 25 years ago (Baldwin, Peleg-Bruckner, & McClintock, 1985), in which prior knowledge increased reading comprehension ( $p < .001$ ). It was observed, in this 7<sup>th</sup> grade class, that topic interest also increased reading comprehension, but that there was no correlation between prior knowledge and topic interest, yet the effects were additive. That is, if a student had both prior knowledge and topic interest, their comprehension was greater than that of students who had either prior knowledge or an interest in the topic. The authors claimed that the confounding of prior knowledge with interest has been a major methodological flaw in educational research (Baldwin, et al., 1985). The authors went on to discuss how older adult perceptions, resulting from increased specialization in knowledge, lead to close correlations between interest and knowledge. This is not the case with “school children who are forced to study a variety of topics whether they like them or not” and “that a group of above average students could be fairly knowledgeable about space exploration and American Indians, for example, without having any real enthusiasm for

those subjects” (Baldwin et al., 1985, p. 498).

If the reading research can be extrapolated, then introductory chemistry students should comprehend the subject better, if they either have some prior knowledge or an interest in the subject. If both prior knowledge and subject interest occur, there should be additive effects upon their comprehension. The UAF course associated current issues with chemistry principles and student knowledge, to stimulate student interest in chemistry. The HU course associated traditional knowledge and customs with chemistry principles, to build upon prior knowledge. The SENCER-SALG survey results, in learning gains, were comparable for either approach.

The surveys indicated generally that students did not claim learning gains for content not included in the course; many UAF students either reported “no gain” or “not applicable,” for questions related to dyes and pigments, which were not part of the UAF CHEM 100 course. While there were variations among responses, with some students reporting learning gains for content not taught; the survey results were similar to those obtained by other SALG researchers, the data support moderate correlations between direct assessment and the SALG, as reported by Weston and Seymour (2006).

Learning to read the Periodic Table of Elements, beyond knowing the names of the elements and their atomic numbers, is one of the main course objectives in an introductory chemistry course. Knowing how electron shells fill, to determine an element’s number of valence electrons, to discern properties of groups of elements, their electron configurations and electronegativities – all are essential to understanding ionic bonds, covalent bonds, chemical formulae and balanced reactions. These are core



knowledge requirements for advanced chemistry courses. Whether introductory students claimed to have prior understanding of the Periodic Table of Elements or not, it would be expected that post-course surveys would indicate gains in understanding. It was not expected that they would necessarily be the highest gains recorded, however. The research of Baldwin, Peleg-Bruckner and McClintock (1985) combined with Dr. Bending's observations would suggest that, for at least some CHEM 100 and CHEM 101 students, prior knowledge and/or topic interest influenced the learning gains reported.

Students, with equal capabilities, may not comprehend as much if they either have less prior knowledge or less interest in a subject. The unanswered question would be how much more would those students be able to learn the next time they approached the subject, if either their interests were piqued or their partial learning became the prior knowledge base needed to excel the second time through?

At HU, the pigment and dye laboratory experiments were primarily designed to teach concepts related to pH, which was one of the last subjects addressed in a one-semester introductory chemistry course for non-majors. Student performance, on direct assessment exams, was no better or worse than student performance in prior semesters, when the experiments from the standard lab manual had been used. This indicated that the content learned or experienced in the lab was no better or worse than in prior semesters. Whether or not students learned pH from the lecture, a standard pH lab, or the dye labs, they consistently reported "good gain" to "great gain" on the post-course surveys at both HU and UAF, when asked about their understanding of pH.

## 5.6 Discussion of the Quantitative Data: Workshops

At the beginning of the workshop for the advanced placement high school students, it was learned that they had not yet begun the unit on pH in their classes. That explained why their understanding of “the chemistry term pH” was not among their top pre-workshop responses and why the post-workshop survey showed that 8 of the 12 students reported “great gain” for understanding “the chemistry term pH” since learning pH was one of the main learning objectives of the workshop.

The advanced placement high school students had an unusually high self-assessment of their understanding of “the Periodic Table of Elements” in the pre-workshop survey (4.8, “a lot”). Since no direct assessment was made, their self-assessment was not disproved, but years of experience teaching inorganic chemistry to incoming freshmen, majors and non-majors alike, dispute the reality of that self-assessment of understanding. Given the meta-analysis study of Falchikov and Boud (1989), which showed students rated themselves higher than faculty did, a direct assessment could have readily determined their actual level of understanding.

Nearly half of the high school students focused their attention directly on the laboratory pH experiments. Although a Yakama elder was present to describe the importance of dyes to his culture and taught the students Sahaptin names for the colors extracted, their lowest post-workshop responses were for “how ideas in this class relate to other cultures” and “how this course relates people to world issues,” with over 40% of the respondents claiming that those ideas were “not applicable.” For them, it was as if the elder was never there.

In the Native American workshop pre-course surveys, as in the university student groups, the highest response for understanding was “the chemistry term pH,” but unlike any other group there was also a high level of understanding of “the importance of dyes and pigments to my culture.” In fact, the bimodal distribution of responses (8 responded “a lot” or “a great deal” and 8 responded “not at all”) directly reflected the cultural differences between the Native American elders and non-Native artisans attending the workshop. The lowest responses were “Native names for dyes and processes in using them” and “how pH and mordants change colors.” Those responses reflected the non-Native’s interests in learning about Native names for dyes and processes and the Native American’s interest in learning about pH and mordant affects on colors.

In the Native American post-workshop survey, the highest gains were reported for “the importance of dyes and pigments to my culture” and “how to obtain and extract dyes and pigments.” As in every other pre/post survey, the highest pre-workshop understandings directly correlated to the highest gains reported in the post-workshop survey, with the exception of “the chemistry term pH.” Although pH was the concept taught in the workshop, it was the application of the concept (using pH to change colors) that resulted in “how to obtain and extract dyes and pigments” being one of the highest gains in the post-workshop survey.

In the Native American workshop surveys, 50-60% of the participants reported “no gains” or “not applicable” to questions asked about content not included in the workshop (balancing equations, names of elements and compounds), indicating a possible higher correlation between their survey responses and actual knowledge gains,

as compared to the university course and high school surveys. When compared to the high school workshop responses, the Native American workshop responses, in the pre-course survey, did not show inflated estimates of understanding. The correctly marked “no-gains” and “not applicable” responses in the post-course survey (for content that was not taught, but purposely included in the survey) were the highest for any group. These responses may reflect more mature self-assessment of understandings and veracity in reporting learning gains, perhaps the lack of grade risk or classroom social pressures.

While not conclusive, there were strong indications that learning environments had a large influence upon the participants’ focus. In the high school workshop, a modern chemistry laboratory environment directed participant focus towards the experiment at-hand, such that many students failed to see a connection between the dye experiment and other cultures, even when a Native American elder was present among them. Contrastingly, the group at the Tamastlikt Cultural Center focused primarily on integrating new knowledge into their existing worldviews and values. In terms of learning theories, described in earlier chapters, the high school workshop survey responses more closely resembled the “knowledge in pieces” or fragmentation theories of diSessa (2005) and others, while the Tamastlikt workshop survey responses resembled the holistic views described by Cajete (2000), along with Witherspoon and Peterson (1995).

In discussions with other SENCER course faculty, one of the goals of a SENCER course is to use an issue (environmental, political, social, etc.) in a course to get students to examine concepts from a different perspective, to challenge their existing knowledge

about something and to re-evaluate their prior understanding of *concepts* (either as noun constructs or as verb processes and actions). In terms of how much participants thought they gained, the SENCER-SALG surveys compared pre-course measured self-assessment of understanding with post-course re-assessments of understanding.

While pH was taught the same way in both the high school and Native American workshops, the learning environment and cultural differences resulted in vastly different outcomes, because the learner had very different “needs” for the knowledge. While the quantitative data provided a substantial amount of information, the participants’ written responses revealed much more qualitative information, described in the next section.

### **5.7 Qualitative Data Results and Discussion**

In addition to the Lichert scale response questions, each of the question-stems solicited at least one written response from participants. For the “understanding” question-stem analyzed here, the pre-course question was “What would you like to understand at the end of this course/workshop?” The post-course survey, related to understanding, contained two questions: 1: “Please comment on HOW YOUR UNDERSTANDING OF THE SUBJECT HAS CHANGED as a result of this class/workshop” and 2: “Please comment on how THE WAY THIS CLASS WAS TAUGHT helps you REMEMBER key ideas.”

What participants wanted to understand, in the pre-course survey, varied considerably. Below are examples, from each of the courses/workshops:

- 1: “how to balance chemical equations and how chemistry works, the nature and behavior of protons, electrons, atoms, and elements and how they interact

with each other.” (UAF CHEM 100)

2: “What natural chemical compound is found in trees of Alaska, that act as an antifreeze, preventing them from dying in severe weather conditions.” (UAF CHEM 100)

3: “More about how chemistry relates to the safety in the petrochemical field. How to be able to understand lethal doses and permissible exposure limits to certain chemicals.” (UAF CHEM 100)

4: “I would like to understand and recognize the formulas of elements on the periodic table. I want to know more about Chemistry, period. I took Chemistry in high school but can’t remember anything!!” (HU CHEM 101)

5: “how to convert what i need to know to do my job accuratly [sic] as an RN” (HU CHEM 101)

6: “balancing equations and understanding how these elements will help me better understand nursing and medical field issues.” (HU CHEM 101)

7: “ I would like to understand how to make natural dyes an how to name them as well. As well as what this has to do with chemistry and/or science.” (High School Workshop)

8: “what i would like to understand at the end of this course is the differnece [sic] between dies [sic] and pigments, the definition of the term mordant and also what dies [sic] and pigments have to do with cultures and world issues.” (High School Workshop)

9: “The necessary processes for converting natural materials to dyes – how to

grind/create pigments” (Tamastlikt Workshop)

10: “How to take ideas learned here and think about nature differently”

(Tamastlikt Workshop)

11: “How women and men did the things I like to do down through time.”

(Tamastlikt Workshop)

University students tended to either focus directly on core concepts in chemistry, or how those concepts would help their careers. Some students were interested in specific applications of chemical knowledge, such as tree survival or petrochemical safety. The high school workshop participants were interested in the dyes and pigments, but questioned whether they had any relationship to chemistry, science, cultures or world issues. Some of the Tamastlikt participants focused on the processes, but many more were thinking about integrating what they learned into their world views (thinking about nature and time).

The post-course/workshop comments were also informative. Representative responses, from each course, reflected not only the differences in learning environments, but also differences among individuals, within those environments. Responses varied substantially, within the same course and between courses. For example, to the question “Please comment on HOW YOUR UNDERSTANDING OF THE SUBJECT HAS CHANGED as a result of this class/workshop,” the following responses were recorded:

1: “ I really haven’t learned very much about the main concepts of basic chemistry, I am still crumbly at balancing equations, I still don’t know anything about reactions or elements...I could not stay afloat in any other

chem classes” (UAF CHEM 100)

2: “I started seeing the difference between science and public value issues. Many times we try to mix those two. It also encouraged me to learn more about the protection of our enviornemnt [sic]. My firend [sic] works in European Comission [sic] in Brusell [sic] and I asked her to send me some information about what they are doing. She did. So it was very relevant and interesting to read in those brouchers [sic] concepts that we actually learned in class.” (UAF CHEM 100)

3: “I completely understand more than I did prior to entering this class. I had actually already taken Chemistry at another college and did not learn as much as I did in this class.” (HU CHEM 101)

4: “I have learned a lot in this class, however my understanding of it all is still somewhat vague.” (HU CHEM 101)

5: “I now have a better understanding on dyes and pigments and how they are extracted” (High School Workshop)

6: “I already knew most of the stuff he talked about.” (High school workshop)

7: “Appreciate our world and the materials provided us and how we can use them.” (Tamastlikt Workshop)

8: “Now I see how changing pH levels can affect outcomes.” (Tamastlikt Workshop)

9: “Won’t be so afraid to try this at home, with some of the everyday things in my house, baking soda, vinegar, iron pills, etc.” (Tamastlikt Workshop)



One notable feature of the SENCER-SALG is the quantity of written communication provided by participants. The amount of information was substantially more than typical end-of-course evaluations used in most university courses. While this study focused on the “understanding” question-stems, educational researchers, experienced in qualitative research methods, might find that SENCER-SALG written responses, in all of the other question-stems combined, could supplement qualitative research methods such as case study and grounded theory. Additionally, the SENCER-SALG’S user-friendly data compilation and demonstrated moderate correlations to direct assessment methods could provide qualitative researchers with easily obtainable quantitative data to support/defend their qualitative studies if critics of qualitative research challenged their results. For example, the student who remarked “I already knew most of the stuff he talked about” also commented:

- 1: “ It helped me learning by showing me that I can say my opinion and not being shy about not being right.”
- 2: “I did say a few things on topics that I remembered or know the answers to.”
- 3: “I learned something new.”
- 4: “I already feel comfortable with my peers.”
- 5: “I already knew most of the stuff he talked about.”
- 6: “He taught it with a lot of interaction.”
- 7: “I like chemistry, since the beginning of the school year.”
- 8: “I know how to make dyes.”

Both quantitative and qualitative educational researchers can utilize the SENCER-SALG

data. Few other assessment instruments are that versatile. Its ability to elicit responses, which have been demonstrated to moderately correlate with direct assessments, along with substantial written comments, is an asset to the instrument. For example, comments from the Tamastlikt workshop differed significantly from the laboratory courses and workshops, especially in learning applications:

- 1: “It was wonderful energy in the class and seeing the finished products by the weavers was inspiring.”
- 2: “Got to see how certain rare materials worked – such as cochineal and indigo – very fascinating.”
- 3: “We connected with local people and others to meet up with later.”
- 4: “I appreciate the openness and the casual approach for us to investigate as we choose.”
- 5: “It clarified differences in chemical reactions I knew nothing about.”

Another example of the instrument’s versatility is the ability to determine if a respondent uses an overall approach to answering questions on the survey, that is by either marking all favorable or all non-favorable responses, without distinction among individual questions. One survey respondent marked “good gains” to every question, whether or not the question content was part of the course. Skilled evaluators can easily find trends like this by looking at individual responses. Likewise, the high school survey responses showed that some participants did not score their understanding low in any area, supporting the high self-assessment findings of Falchikov and Boud (1989). In essence, the survey responses provided more than learning gains; attitudes towards the

learning environment and indications of differing worldviews also surfaced.

One of the greatest values of the SENCER-SALG is the ability to measure *reactions*, level 4 of Bennett's hierarchy of evidence for program evaluation (Bennett, 1976). By evaluating the reactions of people, educational strategies can be changed before negative attitudes and diminished aspirations prevent *Knowledge, Attitudes, Skills and Aspirations* (KASA), level 5 and *practice* changes, level 6. Educational zeal (or pressure from administrators to achieve end results) often circumvents peoples' reactions to educational programs, at the risk of compromising or preventing higher levels of program development. By the time negative reactions have been noticed by an educator, who skipped level 4, it may already be too late.

### 5.8 Summary

The SENCER-SALG described learning gains in two university chemistry courses for non-majors, a high school workshop and a Native American workshop. In all but the Native American workshop, the greatest learning gains in the post-course survey were correlated to the highest claims of understanding in the pre-course survey. The data correlated prior knowledge of content to the highest claims of increased learning gains for that same content.

In the high school workshop, held in a university laboratory, a Yakama elder described the importance of the dyes and pigments to Yakama culture and helped students learn Sahaptin names for the colors extracted. Post-course surveys indicated that nearly half the students still did not associate any of the laboratory activities with culture or world issues, such as genetic engineering of food or safe drinking water. In the

Tamastslikt Cultural Center workshop, participants accurately separated taught/non-taught items on the survey and described direct correlations between the subject taught and their culture. The courses and workshops taught in the laboratory setting were distinguished from the workshop taught in a cultural setting in that the highest laboratory setting learning gains were associated with chemistry content – with one exception. In the UAF course, the content was also related to world issues, a positive reflection upon the goals of that course, an issues-based textbook and teaching focused on world issues. However, the HU laboratory course and high school workshop responses did not emphasize practical applications of chemistry, or chemistry relations to culture. Only the cultural center workshop learning gains indicated an integration of new chemistry knowledge into participants' practices, worldviews and values. The written comments at the Tamastslikt workshop differed significantly from the laboratory courses and other workshops.

## **Chapter 6 Future Directions in Science and Native Science Education**

### **6.1 Introduction**

Every learning environment has its advantages and disadvantages. A student of Western Science usually gains their knowledge within the structured study and research processes of a university setting. How that knowledge and those processes are applied outside of the university is uncertain, but likely it has much to do with personal and cultural beliefs. If an educational system separates students from the natural world, or if it suppresses values and beliefs, that differ from those within the ivory towers, it is a wonder that those students connect any classroom learning to their own cultural values and worldviews. Even culturally diverse education programs may be destroying long-held values and beliefs.

Peter Bates (UNESCO, 2009) suggested that preserving Inuit knowledge in books, maps and CD's represented "Western assumptions about the transmission of knowledge" (p. 96). Bates wrote that moving from the land to permanent housing, and that obtaining store bought foods and clothing through government welfare policies has contributed to sedentary, non-working lifestyles and a separation between Inuit youth and their elders. The elders continue to hunt and travel, but there is a "noticeable silence between the elders and their grandchildren" (p. 97). Bates described traditional roles of elders to help youth "establish and reinforce connections to the land and community," where "young generations were expected to learn by experience within the process of doing, lightly guided along the way by their older relatives" (p. 98). Without experiential learning, Inuit knowledge cannot simply be maintained in books; "these efforts will

mostly prove fruitless without an experiential context . . . only through contact with the land can the distinctive nature of Inuit knowledge be maintained” (p. 104).

Perhaps some balance can be achieved in teaching and learning, where didactic and experiential learning can meet. Kawagley (1995) may not just have been speaking for Native Alaskan communities when he advocated for place-based education. Perhaps some groups of people have wandered through so many centuries and countries, that they cannot remember a time when their language, place, beliefs and knowledge all interconnected. Cajete (2000) described that situation as a “dysfunctional cosmology.” This thesis found differences in application of knowledge that were influenced by where ideas were taught and learned, not by the subject itself. Community turnout was greater when workshops were held away from a university setting, even though a university was closer. Approximately twenty adults signed up at each location for both the HU and Tamastlikt Native American workshops. Twenty-five people attended the workshop at the Tamastlikt Cultural Center but only four showed up for the HU workshop, which was held in a classroom laboratory. The laboratory was a 10-mile drive for many would-be participants; the cultural center was over 100 miles away. The differences in application of knowledge, described in the SENCER-SALG survey results, and the differences in community involvement, both tied to location, suggest that relationships between Native communities and the ivory towers are more complex than some people realize. Long-term efforts by universities, to “help” students adapt to university life have obscured the reality that few of those universities have encouraged professors to seek “help” in adapting to the worlds of their students.

## 6.2 Lingering Effects of Assimilation Attempts

In Chapter 3, Chief Joseph described what it was like for his people, not being able to practice the religion of their fathers, or to live on the land where place-based experiential learning had occurred for millennia. Compulsory education constantly reminds Native students that we have not progressed that far from Indian Boarding Schools. Other students now experience similar modern assimilation techniques. I have many students who are non-science majors and several have told me how much they hated science in secondary school. A frequent reason given was that their teachers taught Western Science as “the Truth” and dismissed their family beliefs as fables. I have commented that nobody, no school system, has the right to deny one’s personal beliefs, scientific or otherwise. Several students have thanked me for allowing them to study Western Science without having to recant everything they believe.

Students’ prior knowledge, whether it was “scientific” or not, influenced their attitudes towards learning, maybe as much as subject interest did. Like researchers who overlook Bennett’s (1976) level 4, *reactions*, scientists who disregard student beliefs as mere opinions and then lament inadequate student progress in scientific thought processes or knowledge content acquisition, might consider the poem *Hudibras*, by Samuel Butler (Butler, 1678, *Hudibras iii.iii.*, [www.englishclub.com](http://www.englishclub.com)):

He that complies against his Will,  
Is of his own Opinion still;  
Which he may adhere to, yet disown,  
For Reasons to himself best known.

Attempts to bring about school compliance, against the will of others, can be found in current news headlines. At the time of this thesis, national attention has been focused on what the Texas Board of Education will influence publishers to include/exclude from textbooks. Both liberal and conservative opponents are striving to have their views incorporated into the curriculum. As the largest purchaser of textbooks, Texas has a substantial influence on what is published and what students in the other 49 states are taught. While this thesis does not dwell long on political and social ideologies struggling for dominance in schools, few people, conservative or liberal, will argue that those struggles do not occur.

A national, compulsory education system has become a high-stakes arena, where ideologues attempt to influence future generations to see the world as they do. Many educators believe in Kuhn's "paradigm shift" and Kuhn's followers have asserted that old ways and traditions are incommensurable with new paradigms, but Toulmin thought that it was a mistake for sociologists to assume that society was a singular, functional social system.

While ideological chasms have widened within academia, Native cultures have continued to strive for their own existence. Science and science education may be prominent aspects of the lives of those working in university laboratories and classrooms, but it is important to acknowledge that Western Science is not as prominent in indigenous thought, or seen in the same context. The Native writers, cited in this thesis, described Western Science as incomplete, not yet integrated into the land, language, beliefs and spirituality of the people. For Native Americans, who choose to interact with the Western



world (rather than being compelled to), science is an area of common interest, an area where cultures overlap. Numerous examples of overlap in astronomy, medicine, geography, geology, environmental science, natural resources and physics can be found in both Western Science and Native Science.

### **6.3 Place-based Research Scientists and Science Educators**

It is my argument that relationships between universities and Native communities will be strengthened by a mutual willingness to exchange places, rather than the status quo of sending the student to the professor's culture. Why should students always have to go to the university to learn science? If more faculty would spend at least some of their time in their students' communities, more students might show up at the university to study science. Place-based science faculty could foster learning environments, which provide students and their communities more flexibility to decide how much, or what aspects of Western Science they choose to incorporate into their worldviews. Those communities would likely support more of their members studying Western Science. Scientists could learn more of the communities' worldviews if they spent time in them, just as the communities have learned more of the scientists' worldviews by sending their people to the universities. The opinions of both might change—especially when nobody has to comply against their will.

Forcing unwilling faculty into the field is the opposite of students being forced to assimilate into university cultures and faculty, accustomed to academic culture, are unlikely to be effective away from it. To be successful, field faculty must not only be willing to work away from the university, they will either need prior field experience or

skilled mentors, who know the communities they are entering. More importantly, the administration within the university, especially if it is comprised entirely of academic professors and managers, must realize that their collective knowledge, skills, traditions, ideologies, policies for faculty and students, still leaves them inexperienced in the administration and management of field faculty within place-based educational learning environments.

University administrations may assume that they have the ability to manage place-based education and research, even though they may not know what it means and have no vice-president or provost level administrator with field experience. Personal observations, also based upon experience, predict that the dominant culture within the ivory towers will have so many voices trying to determine what field faculty should/should not do, that what emerges would be watered-down informal science education, museum exhibits, and after-school programs, such as the narrowly-scoped NSF-ISE initiative. Formerly successful programs, such as Cooperative Extension, at my alma mater years ago, or growing programs, such as the Alaska Native Knowledge Network, will never rise above a subservient role within a university hierarchy that only portends to reach out to communities. Those programs will fail. Field-based faculty, minus an administrator with enough clout to protect them, or enough field experience to lead their efforts, will eventually succumb to Tower-based wills, or they will abandon the organization.

Several research and extension faculty, for example, at a research and extension center less than five miles from my home, were recently informed by the ivory tower

administrators that their programs were being shut down. There was nothing in the paper or on the evening news. One of my former roles, as the area extension agent, was to maintain communication lines among researchers, producers, communities and local governments, through media articles, columns, radio and television interviews, etc. That extension position, which I left amidst serious disagreements 15 years ago, was never refilled. A breakdown in community relationships was probably a major reason for budget cuts and re-direction of university resources.

The only reason that I knew about the layoffs at all was because one of the research scientists came to visit me at work, in our small private liberal arts university. She asked if she could write a research grant proposal to work with us. What a change! I hope the rest of the land-grant system, in other states, does not fall to such depths. Our small school lacks both the infrastructure and human resources to support such efforts, while the state university's fields, tractors, laboratories, equipment, libraries, once the envy of all, are being idled. How well other land-grant universities survive the future may be determined by how well they know the people of their state, how well they extend themselves, how well they respect the land and people who support them, how relevant and responsive they are to what people need and want.

What if a Native community decided how it would address local education, within a larger system, and negotiated educational goals and methods? The status quo isn't working well. Western Science should be able to adapt some of the university and school system to those communities, if requested, and not be surprised if the community does not want everything offered. Native communities have sacrificed much, by sending their

children, usually unwillingly, to Western schools. This may not be what some scientists and educators want to hear. A long term commitment to informal science education (not short-term museum exhibits), combined with negotiated place-based formal education, is a crucially needed initiative for those accustomed to comfort, security and like-minded views within the Towers.

#### **6.4 Implications for a Scientific Future**

Scientists see the natural world neither transparently nor completely. Science in the future will change, if scientists do not find balance between relativism and absolutism, or effectively define what science is/isn't. If rules of conduct and ethics in scientific methods are abandoned or influenced by funding sources, or if ideologues succeed in silencing scientific debate by mandating what, how and where science is taught, the objectivity with which scientists have distinguished themselves from others will disappear into the past. Followers of a new paradigm will produce another re-written history of science. Scientists today are not small groups of privileged initiates into ancient mysteries or lone alchemists, but represent large groups of people, who have created varying definitions for terms like science and concept, definitions influenced by widely different philosophical and political views.

Other scientists could take the place of an experienced natural science professor, with more disastrous results than a collapsed extension system or a field-based science education program that never became fully established. If Western scientists think they can reduce Inuit experiential knowledge in “woods smarts to maps and CD’s as “book smarts,” then future scientists may think they can reduce scientific methods of

experimentation in the natural world to computer simulations in a virtual world. The phenomenal growth of online education cannot be disputed, as evidenced by the successes of Kaplan University and The University of Phoenix. Recorded lectures, by famous professors, with fancy audio-visuals and special effects, are very attractive to paying customers. Successful completion of simulated laboratories may seem more self-satisfying than struggling with all the variables of a real experiment, but those experiments are not real. Simulated science labs are being used to replace wet chemistry labs, genetic transformation labs, and physics labs for online courses. They are even becoming common in R-1 institutions. Virtual science will take science away from the natural world, just as boarding schools removed Native children from experiential learning within their community.

Watch young children play Nintendo's Wii simulation games. Children assume they are becoming bowling professionals with practice, yet they have no idea what effect a 12-pound bowling ball will have upon their balance, their ability to use muscle forces and accelerations to move the ball away from and then toward distant pins, nor do they comprehend the social purpose of bowling in the first place. Likewise, online laboratory simulations give students a false sense of laboratory skills, without appreciation for unpredictable outcomes or all the work it takes to prepare for an experiment, much less how to interact with others to address all the problems they will inevitably encounter. Online science degree graduates would epitomize science imposters. Several online universities are already offering those degrees; more will likely follow. It may be laughable, but it is no laughing matter.

Scientists have also been their own worst enemies. Peers ridiculed Harlan Bretz for many years because of his claims that catastrophic Columbia floods covered the Pacific Northwest, at the end of the last ice age (Bjornstad, 2006). Bretz's detractors had just formed a new scientific discipline called geology, a few years earlier, based upon their uniformitarianism view of gradual processes exemplified by the Grand Canyon. Catastrophism was perceived as a threat to those ideas, so it was rejected. After many years of standing alone in his beliefs (nobody bothered to listen to Native American stories recounting the river flooding), the evidence for catastrophic flooding became overwhelming and catastrophism is now taught alongside uniformitarianism today (Tillery, 2009).

Wegener's Continental Drift Theory was rejected for almost 50 years, because he could not give an acceptable explanation for how continents separated (Tillery, 2009). When technology allowed the bottom of the oceans to be mapped, revealing ocean floor spreading and subduction zones, Wegener's ideas were brought back and incorporated into the "improved" Plate Tectonic Theory. Wegener had already died and never saw that his rejected theory had finally been incorporated into another scientific theory.

The Ptolemaic geocentric universe was accepted for centuries, with complicated retrograde models to explain planetary motion, until Copernicus, Galileo and others defended the heliocentric model, with the sun at the center of our system—at personal peril before the religious leaders of their world (Tillery, 2009). Meanwhile, Mayan astronomers had already charted the paths of planets and stars and had predicted lunar and solar eclipses, transits of Venus and other astronomical events hundreds of years into

the future (Smiley, 1960). They didn't need Galileo or the Church to teach them the heliocentric nature of the solar system or how to find the center of the galaxy.

Practicing scientists could develop future scientists in situ, where they live, within their communities, instead of waiting for the 12th grade survivors of compulsory education – the few whose school experiences haven't destroyed their interest in science or alienated them from the natural world. Scientists will have to rely upon communities for just about everything – especially in remote rural areas. They would collaborate with other teachers, including elders, along with their colleagues back at the university. Rural Alaskans and other rural Native communities, who have nearly been ignored by everyone else, could become a new generation of natural scientists, a generation that actually still lives in the natural world. Some private foundations, tired of the same old programs and politics, or concerned over new trends such as online science degrees, might provide some support to these efforts, especially if communities demonstrated how they could integrate science into their worldview and solve problems nobody else can.

If the status quo isn't working, we can't keep doing the same things and expect anything different to happen. Most universities are competing for an ever-smaller pool of potential science majors each year. Online university degrees in science are still in their infancy, but infants grow. People accustomed to eating hard tomatoes (Hightower, 1972) without knowing what good tomatoes taste like, may become the future students who follow an online scientist, who sits behind a computer and creates virtual laboratories. If people can't tell the difference between a hard tomato and a really good one, perhaps

future university students may not be able to distinguish virtual science from experimental science.

Researchers in science education should also recognize that they are acculturated into their own traditions, distinct from practicing scientists. If they spent more time in appreciation of those similarities and differences, they might establish better working relationships with research scientists. Research scientists often have disdain for the esteem educational researchers have for their pedagogy, and science educators often look for faults in scientific methods and the claimed objectivity of research scientists. One indication of strain in those relationships can be found in a Science journal report (Bush et al., 2008), in which 40% of the California University system science education specialists were ready to leave their current jobs and another 20% were ready to leave the field entirely and move into basic research.

Science is among the losers, when internal arguments and differences are perpetuated between research scientists and science educators. Maybe there are too many kinds of science today, too many different ideas of what science is/isn't. Some differences may never be reconciled; chasms created within ivory towers may never be bridged. Yet, those ideological chasms do not have to exist everywhere. The realities of working in the natural world and the practice of addressing multitudes of community challenges can make ideological chasms seem quite small, in comparison. Perspectives can be altered, when horizons change from the edge of one's desk to those that meet the sea or sky. It will take both research scientists and science educators, working together, to adapt to rural communities, to collaborate with the people there. Both scientists and



science educators will be a long way from the ivory tower, but if they study the world around them, they will survive. Someday, they may return to install a bright lamp in the top of the ivory tower and convert it into “The Lighthouse” (Longfellow, 1849):

“Sail on!” it says: “sail on, ye stately ships! And with your floating bridge the ocean span; Be mine to guard this light from all eclipse, Be yours to bring man nearer unto man!”

### **6.5 Summary**

Compulsory education, especially for Native Americans who remember the legacy of Indian Boarding Schools, is a serious challenge to an unalienable right to liberty. Other groups of people are becoming increasingly concerned that the politics and culture within schools are undermining their own beliefs, and are considering alternative education options for themselves and their children.

Place-based science education, among Native communities, could foster a learning environment where overlapping interests in Western Science and Native Science could be studied without forcing faculty or students to comply with the views of others, against their will. Research scientists and science educators may possibly find that the chasms separating them within ivory towers could shrink when they are viewed in comparison to the real-world challenges they would jointly have to face in place-based community research and education.

Bretz, Wegener and Galileo represent scientists who challenged the status quo within Western Science, but Mayan astronomical knowledge challenged Western Science claims to “discovery” of the heliocentric model, Earths’ orbital period and the precession

of its axis. This thesis has contrasted “book smarts” with “woods smarts,” but they do not have to be mutually exclusive. Knowing that hypothermia can kill you does one little good if you can’t figure out how to stop it, after you run your snow machine into freezing water (Barnhardt, 1986). Knowing how to get water from the roots of a tree does you little good if you are educated to sit in an office and drink bottled water (Van Doren, 1994). Research scientists and educational researchers could collaborate with Native American communities to find ways to help one other become a little bit smarter, in both the woods and in their books.

## 6.6 Epilogue

Slow Bird carefully finished tending the smokehouse fire. He surveyed the racks of salmon and the venison hanging from the rafters before going outside. It had been a good year for fishing. His nets and lines had been prepared; the salmon songs had been sung. When the eagles announced the arrival of the salmon, the people took what fish they needed for the winter. Many more fish went up-river to other people—and to spawn. He had hunted in the modern way though; a rifle was a useful tool.

The shadow of the pine tree was almost to the rock structure called “the Old Man” and he knew his grandsons and their cousins would soon be coming from school. They had been coming to see him more frequently since the new professor, from the university, had come to work with the teachers in this region. The professor came to watch the Elders work with their grandsons at least once a month. The professor did not understand much of the language, but his eyes were full of interest. He didn’t talk too much, either.

The local teacher now came out from the schoolhouse more often. He was Slow Bird’s nephew, one who had learned both Western and Native worlds, one who had studied at the university. It was good that he was interested in what the Elders had to say again. Slow Bird also enjoyed hearing his nephew tell some of the stories from the school.

Today, Slow Bird and his brothers would show the boys how to begin the long process of tanning hides. There were many stories and songs to go along with the work; stories which built character and encouraged persistence. The boys will make the hides into buckskin shirts during the winter. Slow Bird had been impressed that his grandsons

had read in school about the ways their people tanned hides and had learned to ask questions in the native language. Slow Bird's son and wife had left for the city many years ago, before they could learn of his people's ways. When they recently moved back home and placed the boys in the local school, it was a blessing.

Before the professor worked with the teachers, the boys came to visit, but they were unprepared to learn from the Elders, or they were too busy writing their school lessons. Now, the school seemed interested in coordinating what children learned in school with the ways of the people. The teacher also taught the children to ask Elders for permission, before writing anything on paper. Some things were not meant for books, and Slow Bird appreciated the respect.

The soaked hides were ready, the scrapers sharpened. He heard the voices of laughing children in the distance, as Raven called them home. His brother picked up a drum, and they began to sing...

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## **Appendix A**

### **Human Subjects Review Exemption Notification**

Dr. Larry Duffy  
University of Alaska Fairbanks  
The Graduate School  
202 Eielson Building, PO. Box 757560  
Fairbanks, Alaska 99775-7560

Dear Dr. Duffy:

I have reviewed the Application for Review of the Protection of Human Subjects in Proposed Research submitted to be by Greg Van Doren an advisee of yours. Mr. Van Doren's research project Natural Dyes and Chemistry in the Yakama Nation meets exemption from full Human Research Committee Review as specified in 2005 Code of Federal Regulations (CFR) Title 45, Part 46.101.b.1 (i) and (ii) and Part 46.101b.2 and Heritage University. Those exemptions are:

- (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (2) Research involving the use of educational tests, (cognitive, diagnostic, aptitude, achievement), if information taken from these sources is recorded in such manner that subjects cannot be identified, directly or through identifiers linked to subjects.

Even though Mr. Van Doren's study is exempt from committee review he should inform subjects in writing of the purpose of the study and that participation is not required.

Sincerely,

Dr. Raymond L Bending  
Chair Human Research Committee  
Heritage University.

Hello Greg and Larry- I have reviewed the application materials from Greg and Heritage and agree that the proposed activities qualify for exemption under the Code of Federal Regulations. If you require an official exemption letter from the UAF regarding status of your project, please let me know and I can draft one for you.

Thank you-  
Bridget Stockdale

Van Doren, Greg wrote:  
Hello,

Dr. Larry Duffy, chair of my dissertation committee, asked me to contact your office regarding IRB approval. Attached are documents from Heritage University, where my research has met exemption from full Human Research Committee review. Please review these documents and contact me if there are any additional requirements at UAF.

Sincerely,

Greg Van Doren  
Heritage University

-----Original Message-----

**From:** Van Doren, Greg  
**Sent:** Thursday, January 29, 2009 3:20 PM  
**To:** 'GS Dean'  
**Subject:** Human Research Committee Exemption

Hi Larry,

Attached are the "Application for Review of the Protection of Human Subjects in Proposed Research" and a scanned copy of a letter being sent to you, by the chair of our Human Research Committee, Dr. Raymond Bending. His letter stated that the research project meets exemption from full Human Research Committee review at Heritage University. I will look for an email address for the UAF Office of Integrity at the website you provided, and forward this email to that address.

I look forward to our next meeting.

Greg

## **Appendix B**

### **Sample of the SENCER-SALG**

A sample of the SENCER-SALG post-course survey, which was used in this thesis, begins on the next page. It was downloaded as a PDF document, from the author's files at [www.salgsite.org](http://www.salgsite.org). This modified file displays within the margins of the thesis. The files can also be downloaded as Microsoft Excel spreadsheets, but they do not display well within the thesis format.

English Text A

## INSTRUMENT ANALYSIS

[Instrument dashboard](#)

On this page, you can view and download a summary of results from one or more SALG instruments. You can also view results across instruments.

Results displayed for the following instrument

ID	Open Close	Instructor	Course	Semester	Description	N
11891	Mon Nov 23, 2009 Wed Dec 23, 2009	Dr. Larry Duffy	CHEM 100	Fall 2009	UAF Post Course Survey, Companion to HU Chem 101	18 <a href="#">download</a>

If you'd like to aggregate data across instruments, you can add another instrument to this analysis.

Cross tabulate questions

## Frequency distributions of scale results

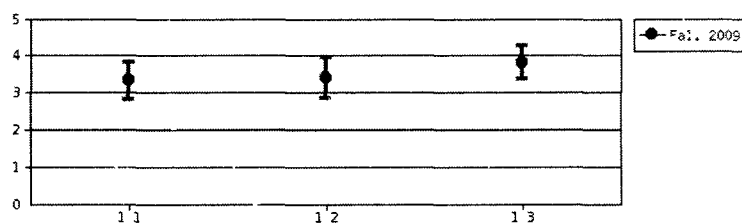
The table below lists the percentage of students responding in each category, along with the mean and number of responses for that item. If you'd like an more detailed analysis, click on the 'details' link to the right of that item.

The Class Overall

	1 no help	2 a little help	3 moderate help	4 much help	5 great help	9 not applicable	Mean	N
1. HOW MUCH did the following aspects of the class HELP YOUR LEARNING?								
1.1 The instructional approach taken in this class	0%	9%	11%	7%	6%	0%	3.3	18
1.2 How the class topics, activities, reading and assignments fit together	2%	7%	6%	13%	6%	0%	3.4	18
1.3 The pace of the class	0%	2%	13%	7%	11%	0%	3.8	18
1.4 Please comment on how the INSTRUCTIONAL APPROACH to this class helped your learning	Enter codes for text answers						—	17
1.5 How has this class CHANGED THE WAYS YOU LEARN/STUDY?	Enter codes for text answers						—	17

## Summary of scale results

The graphic below lists the mean and confidence interval ( $\pm 3$  times the standard error) for each item.



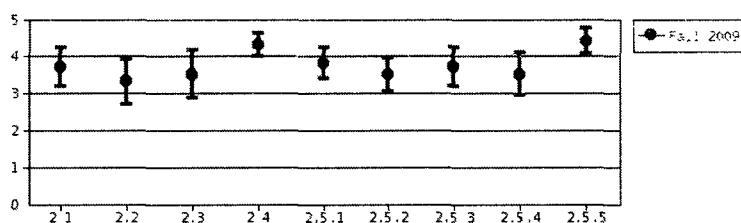
Class Activities

	1 no help	2 a little help	3 moderate help	4 much help	5 great help	9 not applicable	Mean	N
2. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?								
							3.7	18

2.1 Attending lectures	0%	6%	41%	6%	14%	0%
2.2 Participating in discussions during class	2%	7%	9%	6%	7%	2%
2.3 Listening to discussions during class	2%	7%	6%	7%	9%	2%
2.4 Doing laboratory activities	0%	0%	4%	17%	13%	0%
2.5 Specific Class Activities	1: no help	2: a little help	3: moderate help	4: much help	5: great help	9: not applicable
2.5.1 Quizzes	0%	2%	11%	11%	9%	0%
2.5.2 Balancing charges, formulas and equations on whiteboard	0%	6%	11%	11%	6%	0%
2.5.3 Solving problems in class	2%	2%	9%	11%	9%	0%
2.5.4 Repeat exam questions - non graded but checked for evidence of learning	0%	6%	9%	6%	7%	6%
2.5.5 Extra Credit options	0%	0%	2%	11%	13%	7%
2.6 Please comment on how the CLASS ACTIVITIES helped your learning.	Enter codes for text answers					
2.7 Please comment on HOW OFTEN YOU PARTICIPATED in class discussions and HOW THE ATMOSPHERE IN THE CLASSROOM ENCOURAGED OR DISCOURAGED your participation.	Enter codes for text answers					

**Summary of scale results**

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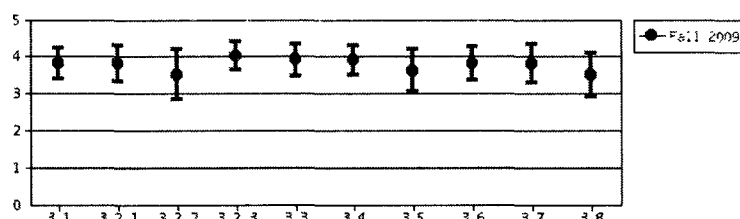
**Assignments, graded activities and tests**

3 HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	1: no help	2: a little help	3: moderate help	4: much help	5: great help	9: not applicable
3.1 Graded assignments (overall) in this class	0%	2%	11%	11%	9%	0%
3.2 Other graded assignments	1: no help	2: a little help	3: moderate help	4: much help	5: great help	9: not applicable
3.2.1 lab journal/notebook	0%	4%	7%	11%	7%	4%
3.2.2 lab photocopy handouts	0%	9%	2%	7%	7%	7%
3.2.3 Exams	0%	2%	6%	17%	9%	0%
3.3 Opportunities for in-class review with instructor	0%	0%	13%	7%	9%	4%
3.4 The number and spacing of tests	0%	2%	6%	17%	7%	2%
3.5 The fit between class content and tests	2%	6%	6%	11%	9%	0%
3.6 The mental stretch required by tests	2%	0%	7%	17%	7%	0%
3.7 The way the grading system helped me understand what I needed to work on	2%	2%	7%	11%	11%	0%
3.8 The feedback on my work received after tests or assignments	2%	9%	0%	15%	7%	0%

3.9 Please comment on how the GRADED ACTIVITIES AND TESTS helped your learning

#### Summary of scale results

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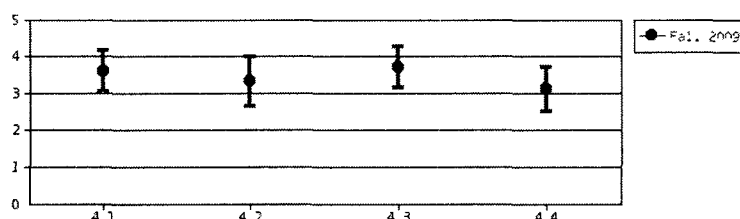


#### Class Resources

4. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	1:no help	2:a little help	3:moderate help	4:much help	5:great help	9:not applicable
4.1 The primary textbook	4%	2%	6%	17%	6%	0%
4.2 Online materials (other than teacher-provided online notes or presentations)	2%	7%	6%	6%	7%	6%
4.3 Visual resources used in class (i.e. PowerPoint, slides, models, demonstrations)	2%	4%	7%	11%	9%	0%
4.4 Dyes and Pigments	4%	4%	4%	15%	0%	7%
4.5 Please comment on how the RESOURCES in this class helped your learning.	<a href="#">Enter codes for text answers</a>					

#### Summary of scale results

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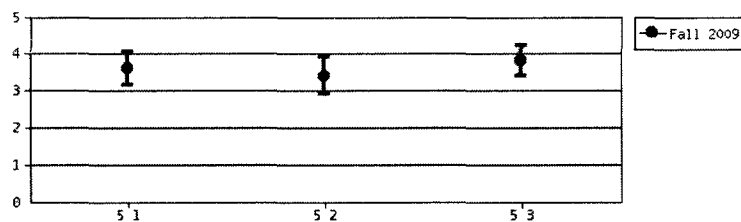


#### The information you were given

5. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	1:no help	2:a little help	3:moderate help	4:much help	5:great help	9:not applicable
5.1 Explanation of how the class activities, reading and assignments related to each other	2%	0%	11%	15%	4%	2%
5.2 Explanation given by instructor of how to learn or study the materials	2%	2%	11%	11%	4%	4%
5.3 Explanation of why the class focused on the topics presented	0%	2%	9%	13%	7%	2%
5.4 Please comment on HOW the INFORMATION YOU RECEIVED about the class helped your learning	<a href="#">Enter codes for text answers</a>					

**Summary of scale results**

The graphic below lists the mean and confidence interval ( $\pm 3$  times the standard error) for each item

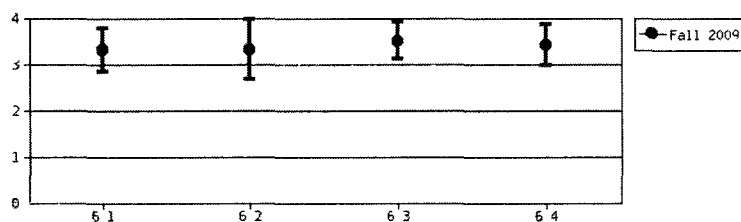


Support for you as an individual learner

6 HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	1 no help	2 a little help	3 moderate help	4 much help	5 great help	9 not applicable
6.1 Interacting with the instructor during class	0%	7%	15%	6%	6%	0%
6.2 Interacting with the instructor during office hours	0%	6%	7%	4%	4%	13%
6.3 Working with peers during class	0%	2%	15%	9%	4%	4%
6.4 Working with peers outside of class	2%	0%	17%	9%	4%	2%
6.5 Please comment on how the SUPPORT YOU RECEIVED FROM OTHERS helped your learning in this class	<a href="#">Enter codes for text answers</a>					

**Summary of scale results**

The graphic below lists the mean and confidence interval ( $\pm 3$  times the standard error) for each item



Your understanding of class content

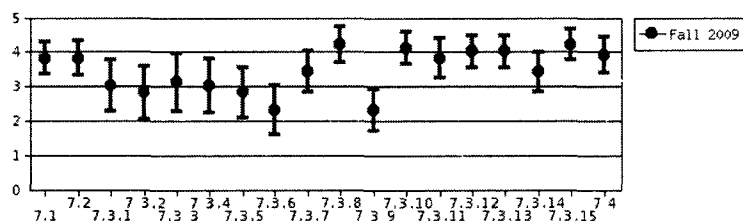
7 As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of each of the following?	1 no gains	2 a little gain	3 moderate gain	4 good gain	5 great gain	9 not applicable
7.1 The main concepts explored in this class	0%	6%	4%	17%	7%	0%
7.2 The relationships between the main concepts	0%	6%	6%	11%	11%	0%
7.3 The following concepts that have been explored in this class	1 no gains	2 a little gain	3 moderate gain	4 good gain	5 great gain	9 not applicable
7.3.1 Preparing materials for dyes or pigments	4%	6%	6%	6%	4%	9%
7.3.2 Differences between dyes and pigments	6%	4%	7%	4%	4%	9%
7.3.3 How to obtain and extract natural dyes and pigments	6%	2%	4%	7%	4%	11%
7.3.4 The importance of dyes and pigments to my culture	6%	0%	9%	4%	4%	11%



7.3.5 Scientific names for dyes and pigments	6%	2%	9%	4%	2%	11%
7.3.6 Local or ethnic names for dyes and pigments	9%	0%	9%	4%	0%	11%
7.3.7 How ideas in this class relate to science in other cultures	4%	2%	6%	15%	4%	4%
7.3.8 The chemistry term "pH"	0%	4%	6%	4%	20%	0%
7.3.9 The chemistry term "mordant"	9%	7%	9%	2%	2%	4%
7.3.10 The periodic table of the elements	0%	4%	4%	11%	15%	0%
7.3.11 Charges and how they determine formulas and compounds	2%	4%	6%	9%	13%	0%
7.3.12 Names of elements and compounds	0%	4%	6%	11%	13%	0%
7.3.13 Balancing equations	0%	2%	11%	6%	15%	0%
7.3.14 Phase changes	4%	2%	11%	9%	6%	2%
7.3.15 How this course relates people to world issues	0%	2%	7%	7%	17%	0%
7.4 How ideas from this class relate to ideas encountered in classes outside of this subject area	2%	2%	6%	13%	11%	0%
7.5 Please comment on HOW YOUR UNDERSTANDING OF THE SUBJECT HAS CHANGED as a result of this class. Enter codes for text answers						
7.6 Please comment on how THE WAY THIS CLASS WAS TAUGHT helps you REMEMBER key ideas. Enter codes for text answers						

**Summary of scale results**

The graphic below lists the mean and confidence interval ( $\pm 3$  times the standard error) for each item.

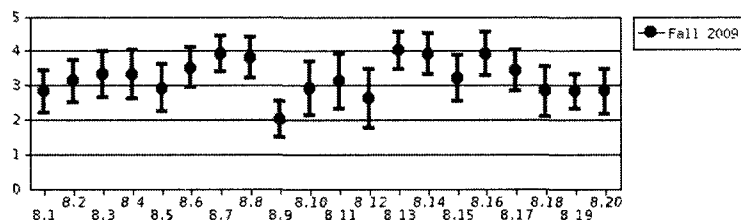
**Increases in your skills**

8. As a result of your work in this class, what GAINS DID YOU MAKE in the following SKILLS?	1: no gains	2: a little gain	3: moderate gain	4: good gain	5: great gain	9: not applicable
8.1 Finding articles relevant to a particular problem in professional journals or elsewhere	7%	7%	6%	11%	2%	0%
8.2 Critically reading articles about issues raised in class	7%	2%	9%	11%	4%	0%
8.3 Identifying patterns in data	7%	0%	9%	9%	7%	0%
8.4 Recognizing a sound argument and appropriate use of evidence	7%	0%	9%	7%	9%	0%
8.5 Writing documents in discipline-appropriate style and format	7%	2%	13%	2%	6%	4%
8.6 Working effectively with others	4%	4%	4%	17%	6%	0%
8.7 Working with laboratory supplies	2%	2%	4%	15%	11%	0%
8.8 Observing and learning from results	4%	2%	2%	15%	11%	0%

8.9 Finding cultural leaders who know about dyes and pigments	7%	6%	7%	0%	0%	13%
8.10 Preparing my own materials for pigments or dyes	6%	2%	6%	7%	2%	11%
8.11 Using my understanding of pH and mordants to change the colors of dyes and pigments	6%	2%	7%	4%	6%	9%
8.12 Speaking about dyes and pigments in my Native language	9%	0%	6%	6%	2%	11%
8.13 Reading the Periodic Table	0%	6%	2%	11%	13%	2%
8.14 Balancing formula units, compounds and chemical equations	2%	4%	4%	9%	15%	0%
8.15 Using an analytical balance	7%	2%	9%	7%	7%	0%
8.16 Recognizing, choosing and properly using laboratory glassware	2%	6%	2%	7%	17%	0%
8.17 Using scientific notation for mathematical expressions	4%	4%	7%	11%	7%	0%
8.18 Using stoichiometry (cross-cancelling) to solve problems	9%	4%	9%	2%	7%	2%
8.19 Using prefixes in the SI (metric) system	6%	2%	15%	7%	0%	4%
8.20 Determining significant figures in calculations	9%	2%	11%	7%	4%	0%
8.21 Please comment on what SKILLS you have gained as a result of this class.	Enter codes for text answers					

**Summary of scale results**

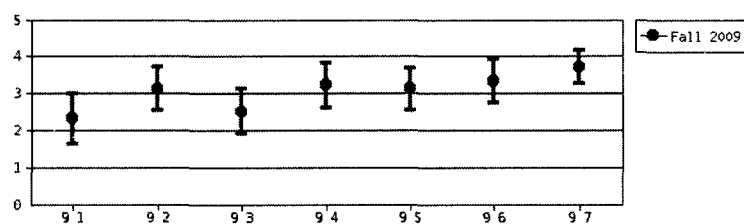
The graphic below lists the mean and confidence interval ( $\pm 3$  times the standard error) for each item.

**Class impact on your attitudes**

9. As a result of your work in this class, what GAINS DID YOU MAKE in the following?	1: no gains	2: a little gain	3: moderate gain	4: good gain	5: great gain	9: not applicable
9.1 Interest in dyes and pigments	9%	2%	11%	0%	2%	9%
9.2 Interest in discussing chemistry with friends or family	6%	4%	11%	9%	4%	0%
9.3 Interest in taking or planning to take additional classes in chemistry	9%	7%	7%	6%	2%	2%
9.4 Confidence that you understand chemistry	6%	4%	9%	9%	6%	0%
9.5 Confidence that you can do chemistry	4%	7%	7%	11%	4%	0%
9.6 Your comfort level in working with complex ideas	6%	2%	6%	17%	4%	0%
9.7 Willingness to seek help from others (teacher, peers, TA) when working on academic problems	0%	4%	7%	15%	6%	2%
9.8 Please comment on how has this class CHANGED YOUR ATTITUDES toward this subject.	Enter codes for text answers					

**Summary of scale results**

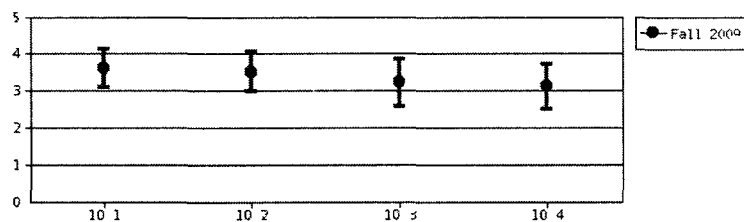
The graphic below lists the mean and confidence interval ( $\pm 3$  times the standard error) for each item

**Integration of your learning**

10 As a result of your work in this class what GAINS DID YOU MAKE in INTEGRATING the following?	1 no gains	2 a little gain	3 moderate gain	4 good gain	5 great gain	9 not applicable
10.1 Connecting key class ideas with other knowledge	4%	0%	9%	15%	6%	0%
10.2 Applying what I learned in this class in other situations	4%	0%	11%	13%	6%	0%
10.3 Using systematic reasoning in my approach to problems	7%	0%	9%	11%	6%	0%
10.4 Using a critical approach to analyzing data and arguments in my daily life	7%	0%	11%	11%	4%	0%
10.5 What will you CARRY WITH YOU into other classes [Enter codes for text answers or other aspects of your life?						

**Summary of scale results**

The graphic below lists the mean and confidence interval ( $\pm 3$  times the standard error) for each item



## **Appendix C**

### **Sample pH/Dye Lab for High School Chemistry**

The sample laboratory experiment, beginning on the next page, was part of an original series of experiments I adapted for outreach use at the Yakama Nation Tribal School (YNTS). That series of experiments resulted in the community involvement which became the basis for the workshops in this thesis. SALG survey data were collected from the YNTS students in 2009, but nearly half the students were already familiar with the workshops, while the other half had no exposure at all. When the SALG survey was adapted for use in this thesis, the mixed group at YNTS was not selected for study.

## Chemistry in Color

### Lesson 4: pH effects on dye colors

#### Quick Review:

Elements can gain or lose electrons to complete (or empty) their outer shell. Elements that gain electrons gain negative charge. Elements that lose electrons gain positive charge. This happens because the number of positive protons no longer balances the number of negative electrons. Charged elements are called ions. Oppositely charged ions are attracted to each other and can form ionic bonds.

One element, hydrogen, has only one proton and one electron. When it loses its electron, and ionizes, it is basically a naked proton (the only ion with no electrons at all). Because it exists in water, and because water is so important to all of us, many scientists study the concentration of hydrogen ions in aqueous (water) solutions.

When written in decimal form, aqueous hydrogen ion concentrations (how many hydrogen ions there are compared to molecules of water) can look like this:

0.00001 (1 in 100,000)

0.000000000001 (1 in 10,000,000,000)

This is hard to read. A simple way to convert these numbers is to use scientific notation. The numbers now look like this:

$1 \times 10^{-5}$

$1 \times 10^{-10}$

The negative superscript (small number above the 10) is called an exponent, and it indicates that 1 is being divided by powers (multiples) of 10. If the superscript is positive, we would be multiplying 1 by powers of 10.

Hydrogen ion concentrations usually range from  $1 \times 10^{-1}$  to  $1 \times 10^{-14}$

To further simplify reading the concentrations, scientists decided to express the concentration as pH. They simply converted the negative power of ten into a whole number.

The original numbers now look like this:

pH = 5

pH = 10

Which pH indicates the highest concentration of hydrogen ions?

### Activity:

Today, you will extract the same dye (color) from cabbage leaves that you extracted from the huckleberries. You will be given the opportunity to study the effects that pH has upon dyes.

Each of you will be provided a test tube with the cabbage leaf extract. It is prepared in the same manner as the huckleberry extract.

There are some small bottles of vinegar (a liquid) and soda ash (a powder). The vinegar increases the concentration of hydrogen ions; the soda ash reduces the concentration of hydrogen ions. By adding vinegar or ash, you can observe what happens to your dye extract. The supplied pH strips allow you to measure any changes in pH

### Directions:

Record the original color of your extract here

Test the solution with a pH strip and record it here

Add a drop or two of vinegar to your extract, with a plastic pipette, and record any observations here:

What do you think happened to the pH?

Test your solution with the pH strip and compare that with your prediction

Now add just a little bit of soda ash and record any observations here:

Record any change in pH:

Continue experimenting, by adding either vinegar or soda, to find a color that pleases you, measure the pH and save that information for future reference:

Based upon your experiments today, what can you conclude about some of the results you obtained last week?